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Nonpoint Source Sampling Design Report Areawide Waste Treatment Management Plan for the Greater Houston Area

Dannenbaum Engineering Corp, Houston, Tex

Prepared for

Environmental Protection Agency, Washington, D C

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NONPOINT SOURCE SAMPLING DESIGN REPORT

JULY 1977

HOUSTON-GALVESTON AREA COUNCIL

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NONPOINT SOURCE SAMPLING
DESIGN REPORT

AREAWIDE WASTE TREATMENT MANAGEMENT PLAN
FOR THE
GREATER HOUSTON AREA
(SECTION 208, PL 92-500)

JULY 1977

PREPARED FOR THE HOUSTON-GALVESTON AREA COUNCIL
BY
DANNENBAUM ENGINEERING CORPORATION/
ESPEY, HUSTON AND ASSOCIATES, INC.

FOREWORD

This document has been prepared by Dannenbaum Engineering Corporation and Espey, Huston and Associates, Inc. as part of a Nonpoint Source Analysis contract with the Houston-Galveston Area Council (H-GAC). The Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) and accompanying regulation require an examination of nonpoint sources of water pollution. The H-GAC has been designated as one of the planning agencies to develop areawide waste treatment management plans under Section 208 of PL 92-500.

This report outlines procedures and recommends considerations with regard to the gathering of a data base for the characterization of nonpoint sources of water pollution within the Greater Houston 208 Planning Area. This report also summarizes existing water quality sampling programs and evaluates their effectiveness in determining the magnitude of nonpoint sources. This volume is Chapter VI of the Nonpoint Source Analysis. Chapter I through V are an assessment of nonpoint sources within the Greater Houston 208 Planning Area; Chapters VII through IX are a catalog of nonpoint source control strategies, costs, and impacts; and Chapter X is an Executive Summary of the nonpoint source assessment and control strategies.

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SAMPLING PROGRAM DEVELOPMENT

Purpose and Objective

The purpose of the sampling program recommendations contained herein is to propose a methodology by which a water quality data base would evolve and be useful throughout the implementation phase of the 208 planning process. The proposed sampling program was directed toward the development of a sampling strategy which will: 1) verify the estimates of the locations and magnitude of nonpoint source waste loads which were prepared during the intensive planning phase of the 208 planning process; and 2) be capable of assessing the effectiveness of any nonpoint source controls which may be implemented.

In the development of a recommended sampling program, this effort was to include an evaluation of all existing on-going sampling programs to determine how best the currently available data could be utilized in the proposed program. It is therefore an objective of this analysis to prepare a critique of the existing sampling programs as to their effectiveness toward the quantification of nonpoint source loads. Since many of the on-going programs are directed toward the detection or quantification of water quality parameters for purposes other than non-point source loads (point source permit violations, public health concern, flood level monitoring, etc.) the critique of these programs was not directed at their capability of fulfilling their primary function, but rather at their potential to also fulfill the needs of the nonpoint source assessment.

Conclusions and Recommendations

From a review of the currently active water quality monitoring programs, it is apparent that no single program has the funding, scope, or sampling density to be effective in an effort to quantify the impact of nonpoint sources of pollution. Each of the existing major sampling programs of the T.W.Q.B., City of Houston Health Department, and the U.S.G.S. are designed to perform the tasks unique to the enforcement, public health protection, or monitoring responsibilities of the respective agencies. As such, and because of a general lack of funding or past public desire for these agencies to expand their efforts to encompass nonpoint sources of pollution, the existing data base is not useful for a statistically reliable quantification of the land use--water quality relationship.

The most serious difficulty with using the existing monitoring systems within the Houston 208 Area for nonpoint analysis is the nonhomogeneousness of the upstream contributory watersheds. Houston's lack of zoning, perhaps a stimulus to its continued growth, has yielded few areas of homogeneous land use within the more concentrated urban areas of the city. This mix of residential, commercial, and occasional industrial land use types in areas upstream of many monitoring stations makes the task of developing land use--water relationships a technical impossibility.

In the City of Houston Wastewater Management Plan published in 1974, approximately 400 sanitary sewer overflows were identified within the metropolitan area served by the Houston treatment facilities. During the storm events that produce nonpoint pollution, the sanitary sewers are simultaneously surcharged with excessive amounts of infiltration water. The infiltration results in the overflows which add to the pollution load carried by the streams and measured at the monitoring stations.

If it is assumed logically that stormwater runoff or nonpoint pollution of a noncontinuous nature will only occur during or immediately after a rainfall event, it can be statistically calculated how many of the routine grab samples taken by the sampling agencies will be coincident with the rainfall event and useful for nonpoint analysis. If the ratio of the number of samples per year at a monitoring station to the number of days in a year is multiplied by the annual average number of rainfall-runoff event-days in the Houston area, the result will be the probable number of water quality grab samples per year that were taken during a period of runoff. For monthly or quarterly grab samples, this probable number is usually one or less.

It is strongly concluded by this report that only event-type sampling of an intensive nature, as was done with the Woodlands-Rice University project can be effective in a program of nonpoint pollutant identification and quantification.

It is a further assumption of this report that the key to nonpoint quantification is the development of acceptable land use water quality relationships. It was for that reason that one of the first efforts of this investigation was to combine for the first time the mapping efforts of the H-GAC staff with regard to land use, point sources of discharge, and all water quality monitoring stations. Because of the amount of detail such a map entails, it is not reproduced with this report but is available from the H-GAC staff to interested individuals. In addition to land use and point discharges, the supporting soil types which underlie the land uses and are cut by the stream channels also substantially impact stream quality through bed and bank scour. As mentioned previously, the sanitary sewer overflows within the City of Houston collection system also have substantial impact on stream water quality during runoff events.

In an effort to quantify the upstream loadings as a result of point source discharges, an attempt was made to inventory all point source discharges upstream of each water quality monitoring station. That inventory, included as Appendix A of this report, included both permitted and actual flow and waste characteristics of all discharges for which effluent data were available from the 1976 T.W.Q.B. print-out of self-reporting data.

It is recommended that no additional funding be expended to intensify the existing system of grab sampling in the H-GAC area for the purposes of nonpoint source monitoring. It is concluded that doubling, tripling, or increasing ten-fold the sampling frequency of the existing programs would not significantly improve the statistical reliability of these efforts with regard to their usefulness in nonpoint pollution source quantification.

Any effort or expenditure for nonpoint source quantification should be directed only to event sampling or areas of uniform land use and soil characteristics or to areas of changing land use when that particular water quality impact is of interest.

A nonpoint source sampling program would require an organization and structure capable of substantial expansion and contraction in staff size without excessive cost. In this regard, it is recommended that any program of intensive sampling be conducted with the aid and assistance of the local university environmental studies programs. As has been evidenced in many water quality programs, student labor can provide a ready supply of relatively inexpensive labor. To avoid problems of repeatability and to assure quality control, the student efforts should be monitored by faculty personnel and by laboratory analysists from the local T.W.Q.B. and U.S.E.P.A. offices. In addition to quality control, university faculty personnel could provide a management function and a coordination effort for the student labor.

It should be unnecessary to create any additional, special purpose organization simply to monitor and quantify nonpoint sources of pollution. It would be far more efficient to expand or draw upon the combined resources of the Houston Health Department, H-GAC, T.W.Q.B., E.P.A., and other local organizations than it would be to create an overlapping, duplicative structure. In this manner, any specially funded investigation could draw upon the funding management, computer capability, and data processing skills of the H-GAC personnel, could tap the universities for a ready supply of concientious labor, and could utilize the laboratory and sampling facilities of the Hosuton Health Department, the T.W.Q.B., and E.P.A.

It is not recommended that stormwater sampling be conducted in the heavily developed portions of the City of Houston in areas where sewer overflows occur. Such overflows or mixes of land uses and densities can only confound the most exhaustive sampling program. It would be far better to defer such sampling until after the City of Houston accomplishes its wastewater collection system revitalization. Until then, those areas should only be sampled in such a manner that the upstream and downstream loads are quantified and the resultant change is ascribed to the broad classification of "inadequately sewered, mixed useage, urbanized area."

Any nonpoint source quantification program should attempt to utilize data collected from other sources than mentioned herein for discrete land use types. For example, in the Ship Channel area where industries have been required to install stormwater collection and treatment facilities, effort should be made to obtain the influent and effluent data of these industries for use and extrapolation to similar areas in other locations.

Because of the cost, labor, and effort necessary to establish a streamflow discharge rating for a monitoring point, is recommended that any nonpoint sampling program include as monitoring points the U.S.G.S. or Texas Water Developemnt Board flow gaging stations in the area of interest.

Because of the prior investment in the quantification of runoff from the Woodlands Development, it is recommended that any nonpoint source quantification program include a continuance of the work done there as an effort to quantify the impact of those land uses in a forested area on those characteristic soil types.

In a quantification program it is recommended that the number of land uses to be evaluated for impacts be restricted to a very few and no more than three-four, at any time such that the number combinations of variables do not exceed the ability of the researchers to statistically evaluate. The U.S.E.P.A. is currently funding a nonpoint source program conducted by a group of Maryland University instructors. That group, called the Chesapeake Research Consortium, is attempting to quantify the impact of five separate land uses on five watersheds through the use of five simultaneous loading equations. This type of analysis is currently the highest state of the art of nonpoint pollution quantification and would be recommended for any future effort in the Houston area.

Any water quality monitoring program for nonpoint sources of pollution must have corresponding rainfall data of equal reliability or the development of pollutant load-rainfall relationships will not be possible. The U.S.E.P.A. has published the recommendation of the consultants who developed the Stormwater Management Model that the raingage density for nonpoint quantification and model calibration efforts should be, as a minimum, four per square mile.

Considering that the current rainfall monitoring network in the 208 Study Area consists of only a handful of stations in thousands of square miles, such a desired density may seem excessive, but in consideration of the number of water quality monitoring points that would be necessitated, the requirement is not so unreasonable. The collection of water quality data without corresponding rainfall and runoff data would be a futile exercise.

Scope of Work

As required by the contract for engineering services, the sampling program development task utilized the information on various types of nonpoint source pollutants and their relationship to land use activities to design a water quality sampling program which was capable of readily identifying the causual effects of nonpoint source pollution. Such a causual relationship was to be capable of more accurately defining the nonpoint source impact to area streams. Ultimately, such a relationship would assist in the assessment of alternative technical solutions to water quality problems.

By direction, the sampling program investigation concentrated on the intensive sampling of water quality in selected areas, rather than broad areal sampling across the 208 area. Because nonpoint load assessment becomes increasingly complex with an increase in the diversity of potential waste contributors, proposed sampling sites were determined for specific contributory land use patterns and for different levels of development within drainage basins. As an additional consideration, emphasis in sampling program development was placed on event sampling as opposed to fixed interval sampling.

Inputs to the sampling program development included: 1) the various nonpoint impact assessment tasks performed by the 208 study area; 2) an inventory of the monitoring programs of other agencies prepared by the City of Houston; and 3) the land use mapping and projections accomplished by the H-GAC.

The primary output of the sampling program development is the detailed specification of a water quality monitoring program which includes specific locations of sampling sites and the parameters to be measured at each site. The output also includes: 1) a narrative explaining the procedure for incorporating additional water quality data into the waste treatment management program update process; 2) a procedure for coordinating the proposed monitoring program with existing sampling programs; 2) maps showing existing and proposed sampling locations; 4) tables specifying sampling station locations, frequency of sampling, and type of sampling to be accomplished at each monitoring station.

As mentioned in the purpose and objective, the output from this sampling program development includes an assessment of the existing water quality monitoring programs maintained by various public agencies. Those sampling programs have been evaluated to determine if they could be modified to satisfy the monitoring requirements of a sampling program directed toward the quantification of the nonpoint pollutant source loadings.

Sampling Program Considerations

Water Quality Characterization

Introduction. In the evaluation of the impacts of storm-related runoff in the H-GAC intensive 208 planning area, it is imperative to realize that monitoring the water quality of streams will not give a direct correlation to the contributory or causative land use acitivity. In addition to the overland runoff or nonpoint pollutant sources considered in this consultant activity, the water quality of area streams is impacted by the following three sources of contaminants: 1) point source discharges; 2) overflows from surcharged wastewater collection systems; and 3) storm sewer discharges which bring an accumulation of nonpoint source pollutants to the streams as a non-permitted (NPDES) discharge. Each of these potential sources may have like or unlike elements which must be accounted for in the cumulative load witnessed at the downstream sampling location. Because of these like and unlike elements, the identification of each pollutant source is a function of the definitions or water quality parameters chosen for investigation. If, for example, the investigating public entity is concerned only with the traditional parameters of BOD(5) and TSS, significant potential stream contamination will not be identified when the point source and urban runoff waters contain significant levels of other contaminants such as heavy metals.

Because of the work effort and expense involved in a water quality characterization, it is essential that the sampling program be developed to fit the particular pollutant source-impact situation of the area. The location of sampling sites and measured parameters must be designed such that they will will not only satisfy the requirements of the program, but also be capable of execution within the limits of time and budget.

A full description of water quality problems or water quality components of problems requires identification of the location, nature, and magnitude of the pollution sources as well as the resulting impact on water quality. Preparation of a complete water quality sampling program may be relatively each in the case of individual point sources of waste which have been or can be readily monitored and where ambient water quality changes can be directly related to specific effluent. In other and more complex cases, arriving at an adequate description of the problem may constitute a major portion of the planning process.

Nonpoint sources of pollution occurring with variable severity throughout an area or different portions of an area and in conjunction with one another present a particularly difficult task for analysis. Component parts of such pollution loads must be identified and qualified in at least general terms. Otherwise, corrective actions may be proposed on a more or less arbitrary basis without assurance or even a knowledgable estimation of their potential success.

One inherent weakness with many water quality monitoring programs is the lack of comprehensiveness in the program with regard to either temporal scale or intensity of sampling. Thus, while many short-term sampling data may be available from a source such as a university, the data are rarely sufficient to provide information beyond that of an indicator nature. Because such programs are usually limited in funding or time, correlative data on all contributory factors are rarely available. It is important for accurate problem definition that time-synchronous data on rainfall, runoff hydrology, runoff characteristics and receiving water conditions and hydrology be included in the sampling program. As a result of a usual lack of comprehensiveness, most monitoring and surveillance data tend to indicate effects rather than give insight into causes.

Also because of economics, monitoring programs usually collect limited grab samples at widely dispersed sites under a variety of conditions. Such data rarely provide quantitative knowledge. Measurements of runoff characteristics and impacts are useful only with respect to their relationships with each other and with the associated conditions under which each sample was taken. Because the inherent sampling and analysis errors in water quality monitoring are relatively large, a substantial number of sample sets are therefore necessary to define a range of error as an index of inherent variability.

One of the most needed and easiest informational requirements to satisfy in a comprehensive water quality monitoring program is the establishment of an operational rain gage network in the area under study. Consultants at the EPA-sponsored Urban Stormwater Management Seminars in Atlanta, Georgia, November, 1975, indicated that the minimum rain gage density for a quantification analysis should be four gages per square mile. Obviously, such a requirement is feasible only with relatively small study areas. The length of time for rainfall monitoring is somewhat dependent on the variability of local rainfall patterns which is higher in the Southwest than areas such as the Northeast, In a statistical evaluation of rainfall events done by the National Oceanographic and Atmospheric Administration, one of the findings was that 85 percent of the various intensity and duration rain events for a given location will be experienced in 2.3 years with 90 percent confidence. As a result of that study, the U.S.E.P.A. Office of Research and Development maintains that a minimum of three years of data collection on rainfall, runoff loads, and receiving water impact are necessary. Fortunately, such a requirement does not mean that every runoff event must be sampled if the agency conducting the study can document that a statistically selected number of events per season over the three year period may be sufficient.

Within the research that has been conducted on urban stormwater in the last few years, substantial work has been done to predict the deposition rates of pollutants on urban surfaces as a function of traffic and land use. Further, by the use of special vacuum sweepers and street rinsing equipment, the surfaces can be sampled to determine the potential pollutant load available for flushing. Unfortunately, data has not been developed for the determination of site specific pollutant accumulation rates as opposed to the deposition rates, nor has work been done to determine attenuation factors for pollutant runoff loading.

In the work that has been done to measure the impacts of urban runoff, the relationships between the pollutants on urban surfaces available for flush and the mass emission being discharges in wet weather have not been established. In other words, a mass balance has not been obtained. While the generalitites, such as dirty land use - dirty runoff and uncontrolled surface modification - heavy sediment loads, have held true, given pollutant runoff loads as a function of surface samples have not been repeatedly predicted. This lack of a definitive relationship is caused by the above mentioned attentuation of some pollutants as they are transported from the surface to the receiving water body. Sediment loads are frequently higher than predicted while organic content is lower. EPA has speculated that the failure in prediction has been a result of the inherent and inadvertant errors in flow sampling and analysis techniques. Further speculation as to this quantification difficulty will be offered in the following paragraphs.

Urban runoff, although in a liquid form, has characteristics which prevent reproducibility of results for certain standard parameters. Secondly, when the urban surfaces are sampled, the dry dust and dirt must be analyzed for pollutants for which standard methods were developed considering a wastewater medium. Therefore, modificaitons to these methods have to be made in order to analyze particulate urban surface deposits. Most of these modifications need to be further evaluated and improved. A few specific examples are:

a) the digestion procedure used in the estimation of heavy metals in roadway deposits should be tested to insure that quantitative recoveries are achieved, b) the inability of the classical BOD method to deal with these types of samples because of inhibitory factors, and c) methods for the determination of rubber and asbestos need to be upgraded, the asbestos analytical method in particular.

Additionally, there are other considerations in data interpretation. As an example, indicator coliform counts are important in assessing the sanitary quality of wastewaters and water bodies. The use of the same characteristics to assess the sanitary quality of runoff unmixed with sanitary sewage from an urban area could result in misleading conclusions. Such a conclusion could lead to a disinfecting requirement when in fact it is not needed and may do more harm than good.

The collection of a wastewater sample that is representative of the source in all respects of interest is a frequently underrated task; a situation that is unfortunate in view of the complexities involved, especially if suspended solids are present, as will be the case with most stormwater flows. In the H-GAC area, where a number of governmental agencies sample the discharge and quality of streams, it is necessary to understand the principles of solids conveyance in order to appreciate the potential variability that can be expected in the data. Even under well controlled laboratory conditions, the study of suspended solid laden flows remains very difficult, with considerable data scatter the rule and statistical treatment of results being usually required. The transport of solid particles by a fluid stream is an exceedingly complex phenomena and no complete theory which takes into account all of the parameters has yet been formulated. It normally occurs as a combination of bed movement, siltation, and suspension. Although these are interrelated, they are usually discussed separately.

The distribution of suspended solids or sediment in a transport stream is expressed in terms of concentration in one of two ways. Spatial concentration is defined as the quantity of sediment relative to the quantity of fluid in a fluid-sediment mixture. Thus, it could be expressed as the dry weight of solids per unit volume of water-solids mixture. There are three such concentrations that may be of interest: spatial concentration at a point in the cross section which is the concentration in a small volume at the point; spatial concentration in a vertical which is the concentration in a small water column extending from the streambed to the water surface; and spatial concentration in a cross-section which is the concentration of the mixture contained in a unit length of channel at the cross section. Turbidity, density, and other fluid properties of the water-solids mixture are related to the spatial concentration.

On the other hand, the discharge-weighted concentration is defined as the quantity of suspended solids relative to the discharge of the fluid-solids mixture. Thus, it could be expressed as the dry weight of solids in a unit volume of discharge, or the ratio of the dry weight of solids discharge to the weight of the water solids discharge. Again there are three such concentrations that may be of interest: discharge-weighted concentration at a point in the cross section; discharge-weighted concentration in a vertical; and discharge-weighted concentration through the entire cross section. The discharge-weighted concentration may be multiplied by the overall stream discharge to obtain suspended solids discharge.

Although a number of theories on the suspension of solids in flowing water have been proposed, it is now generally recognized that it is directly related to the turbulence of the flow. In turbulent flow the instantaneous current vector has vertical and lateral components as well as the horizontal one, and these are constantly changing in magnitude and direction with time in a random fashion. Thus, through turbulence, homogenity is obtained in the potential water quality sample. The important consideration here is that while turbulence is important to the selection of a representative water quality sample, such a turbulent condition is not compatible with most methods of open channel flow measurement where the channel condition could be described as "mild". While the Texas Water Quality Board, therefore, may select a water quality monitoring station where substantial mixing of pollutant discharges and streamflow may be assured; the U.S. Geological Survey on the other hand, will select a streamflow gaging point where turbulence is at a minimum and steady, uniform approach velocities are assured. Because each agency has its own requirements that must be met, it is likely that the monitoring stations for water quality and quantity will not coincide as a waste treatment management agency might desire.

Sediment carried in suspension is acted on in the vertical direction by momentary currents which move upward or downward in the stream. Because the water level in the stream remains unchanged, the quantity of upward and downward flow must be equal. If the upward and downward currents were the only forces affecting the vertical movement of sediment, complete mixing would soon take place and the concentration of sediment would become uniform through the depth. However, all particles of specific gravity greater than that of water settle steadily downward. Under the combined action of vertical currents and gravitational force, a particle caught in a current moving upward at a rate greater than the settling velocity of the particle should be transported upward, but if it is suspended in water moving downward, or moving upward at a rate less than its settling velocity, the particle should move downward. It might seem that the downward currents would take down as much sediment as the upward ones carry up, with the result that all the material finally would settle to the bottom. However, as settling takes place the sediment concentration increases toward the bottom, and the upward currents travel from a region of higher concentration to one of lower concentration, whereas for the downward currents the opposite relation prevails. As the amounts of water moving upward and downward are equal and the sediment concentration in the rising currents is potentially greater than in downward currents, more sediment must be acted upon by the rising than by the falling currents. The settling action superimposed on the fluctuating upward and downward currents tends to produce a balanced suspension in which the rate of increase in sediment concentration toward the bottom depends upon the degree of turbulence in the stream and the settling velocity of the suspended particles. (1) As a result of these movements, the concentration near the mid-depth and bottom are almost always greater than those near the surface; and those near the mid-depth are almost always greater than those near the bottom. Thus, the sample taken by one monitoring agency or individual can vary substantially based solely on the sampling technique or procedure utilized in the field. It is because of these physical realities which create variability that stormwater runoff data lends itself to the smoothing out of statistical manipulation as was done with the Greater Houston 208 data in the urban runoff impact analysis.

Sampling Parameters

To accomplish the characterization of urban runoff, sampling for certain basic wastewater parameters is essential. Considering all the organic and inorganic compounds which can be available for flushing from land surfaces or within stream waters as a result of wastewater discharges, the list of sampling parameters would be near endless. Perhaps because the average planner or engineer is not deeply versed in wastewater chemistry, most discussion and concern are expressed in the utilization of the parameters 5-Day Biochemcial Oxygen Demand (refered to as Biological Oxygen Demand in some fields), Total Suspended Solids, and occasionally an indication of the coliform presense. For the purposes of this report, the water quality parameters of concern are grouped into the following more important classifications.

Oxygen Demand. It is universally accepted and easily understood that the dissolved oxygen concentration in streams or a receiving water is a critical criteria in water quality characterization. The presence of aerobic organisms, including fish, is usually identified with what is termed a "healthy" stream and the presence of anaerobic organisms or the lack of dissolved oxygen in streams is usually identified as an "unhealthy" stream.

The oxygen demand indicator should indicate the effect of the addition of the discharge or, the oxygen content in the receiving water. That is, it should give an indication of the total oxygen demand on the water. Additionally, the method should have a standard procedure and precision so that valid comparisons can be made for discharges entering widely different receiving waters. Unfortunately, there is no single analytical test, particularly the BOD(5) analysis, which will consistantly and effectively express the actual oxygen demand on a stream. The following paragraphs summarize the more common oxygen demand indicator analyses.

1) Biochemical Oxygen Demand (BOD)

This test is used for determining the relative oxygen requirements of municipal and industrial wastewaters. Application of the test of organic waste discharges allows calculation of the effect of the discharges on the oxygen resources of the receiving water. Because of the inhibitory effects of heavy metals on the BOD analysis, several researchers have found it not to be reliable for the characterization of urban runoff. The BOD test is an empirical bioassay-type procedure which measures the dissolved oxygen consumed by microbial life while assimilating and oxidizing the organic matter present. The standard test conditions include dark incubation at 20°C for a specified time period (often five days). The receiving water's actual environmental conditions of temperature, biological population, water movement, sunlight, and oxygen concentration cannot be accurately reproduced in the laboratory. Results obtained, therefore, must take into account the above factors when relating BOD results to stream oxygen demands.

2) Chemical Oxygen Demand (COD)

This test provides additional information concerning the oxygen requirement of wastewater. The test result should be considered as an independent measurement of organic matter in the sample, rather than as a substitute for the BOD test. The analysis method determines the quantity of oxygen required to oxidize the organic matter in a waste sample, under specific conditions of oxidizing agent, temperature, and time. For combined sewer overflows and urban stormwater, COD may be more representative of oxygen demand in a receiving stream because of the presence of metals and other toxicants which are relatively nonbiodegradable.

Since the test utilizes a rigorous chemical oxidation rather than a biological process, the result has no consistent, defineable relationship to the BOD of the waste that can be applied to any sampling stie. In certain applications such as at a wastewater treatment facility where a period of record can be utilized to establish a relationship between the waste stream's BOD and COD, correlation between the parameters can usually be obtained. Such a correlation then becomes operationally significant since the operator can have the results of a COD analysis relatively quickly compared to the wait involved in the five-day BOD analysis. In the analysis of urban runoff waters which are highly varient in their pollutant content, however, a single COD/BOD relationship cannot be applied to all sampling sites.

3) Total Oxygen Demand (TOD)

This test is a recently developed analysis to measure the organic content of wastewater. In the analysis procedure, organic matter in the wastewater is converted to stable end products in a platinum-catalyzed combustion chamber. The test can be performed quickly, and results can be correlated with the COD in certain locations and applications.

4) Total Organic Carbon (TOC)

This test is still another means of measuring the organic matter present in water which has found increasing use in recent times. The test is especially applicable to samll concentrations of organic matter. In this analysis method, a microsample of the wastewater to be analyzed is injected into a catalytic combustion tube which is enclosed by an electric furnace thermostated at 950°C. The water is vaporized and the carbonaceous material is oxidized to carbon dioxide (CO_2) and steam in a carrier stream of pure oxygen or air. The oxygen flow carries the steam of CO_2 out of the furnace where the steam is condensed, and the condensate removed. The CO_2, oxygen, and remaining water vapor enter an infrared analyzer sensitized to provide a measure of CO_2. The amount of CO_2 present is directly proportional to the concentration of carbonaceous material in the injected sample.

Considering the advantages and disadvantages of the various oxygen demand tests or indicators and the accepted usage, it has been suggested by the U.S.E.P.A. Office of Research and Development that the two analytical tests of BOD(5) and TOD be run in all urban runoff quantification projects, E.P.A. notes that, while it may not be convenient to run both tests as an estimate of a single parameter, the importance of oxygen demand dictates special consideration. In all likelihood E.P.A.'s recommended use of the BOD(5) analysis is in cognizance of the potential inhibitory effects of heavy metals, but is with the realization that the correlative data developed over the years by other researchers or agencies will invariably contain analysis results for BOD(5) since it is such a classic and universally applied analysis technique.

Particulate Concentration. Solid materials or particulates represent a large fraction of the pollutional load in urban runoff. While the non-engineer may feel that solids measurements and quantification should be the most definitive water quality parameter, the actual subclassifications of solids can confuse even the experienced planner or engineer. The terms total solids, volatile solids, fixed solids, organic solids, inorganic solids, filterable solids, non-filterable solids, suspended solids, dissolved solids, and settleable solids present a formidable list of definitions. An understanding by the layman is not assisted by the fact that many of the above terms mean exactly the same thing depending on the educational bankground or preference of the individual.

Undoubtedly, the easiest solids expression to become familiar with is the term "total solids". Strictly speaking, all matter except the water contained in liquid materials is classified as solid matter. The usual definition of total solids, however, refers to the matter that remains as residue upon evaporation and drying at 103 to 105°C. Total solids determinations are ordinarily of little value in the analysis of polluted waters and domestic wastewaters because they are difficult to interpret with any degree of accuracy. In most instances the dissolved solids present in the original water represent such a large and variable percentage of the total amount found in the polluted wastewaters that it is impossible to evaluate data, unless the amount of solids originally present in the carriage water is known. The test was originally devised as a means of evaluating the amount of polluting matter present in wastewaters. Since the BOD and COD tests are capable of evaluating the strength of such materials much more exactly, there is little justification for running total-solids tests for such purposes.

Before continuing this discussion with brief definitions of the subclassifications of total solids, it would be valuable to describe the duplication of terminology in the following table. The headings "Engineer's Preference" and "Chemist's Preference" generally describe the individual's choice of terminology; however, the classification is not invariant since many engineers learn wastewater chemistry in the Chemistry Department of their particular university and the opposite situation may occur at other campuses.

COMMON WASTEWATER SOLIDS EXPRESSIONS

Engineer's Preference		Chemist's Volatile Solids		Common Definition
Organic Solids	=	Volatile Solids	=	Solids that "burn" off at 600°
Inorganic Solids	=	Fixed Solids	=	Solids that remain after ignition
Suspended Solids	=	Non-filterable Solids	=	Solids which can be filtered out
Dissolved Solids	=	Filterable Solids	=	Solids which pass through filter

One of the major objectives of performing solids determinations upon domestic wastes, industrial wastes, and sludge samples is to obtain a measure of the amount of organic matter present. This test is accomplished by a combustion procedure in which organic matter is converted (volatized) to carbon dioxide and water, while the temperature is controlled to prevent decomposition and volatilization of inorganic substances as much as is consistent with complete oxidation of the organic matter. The loss in weight is interpreted in terms of organic matter. The standard procedure is to conduct ignitions at 600°C. The matter which remains after ignition is the fixed or inorganic solids.

The settleable- and suspended-solids determinations are of greatest value in assessing the strength of domestic wastes and lightly polluted waters. The determination of settleable solids is of particular importance in the analysis of wastewaters. The test is ordinarily conducted in an Imhoff cone, allowing 1 hr settling time under quiescent conditions. The term settleable solids is applied to solids in suspension that will settle, under quiescent conditions, because of the influence of gravity. Only the coarser suspended solids with a specific gravity greater than that of water will settle. Sludges are accumulations of settleable solids. Their measurement is important in engineering practice to determine the need for sedimentation units and the physical behavior or waste streams entering natural bodies of water.

The suspended-solids determination is extremely valuable in the analysis of polluted waters and sewage. It is one of the major parameters used to evaluate the strength of domestic wastewaters and to determine the efficiency of treatment units. The preferred analysis technique is to filter a sample of water through filter paper and determine total solids in the filtrate. The difference between total solids in unfiltered and filtered samples is a measure of the suspended solids present. In stream-pollution-control work, all suspended solids are considered to be settleable solids, as time is not a limiting factor. Deposition is expected to occur through biological and chemical flocculation; therefore measurement of suspended solids is considered fully as significant as BOD.

The measurement technique for the quantification of particulate concentration that has been recommended by the U.S.E.P.A. Office of Research and Development for urban stormwater analysis is the suspended solids residue determination. The analysis technique is considered routine, is not time consuming, and if desired, additional steps can give the fixed and volatile portions. The selection of additional solids tests is dependent on the data needed to assess unique upstream conditions.

Pathogenic Indication. Although the coliform bacteria group has been a classic criteria for the assessment of pathogenicity, the technique is not necessarily a sensitive indicator of pathogenicity as far as urban runoff is concerned. The parameter is critical, however, in areas such as Houston where treatment plant by-pass or sewer system overflows occur and must be considered in the water quality impact assessment. The coliform bacteria in general are a relatively large family of bacteria not all of which emminate from "Objectionable" or potentially harmful sources; for example, runoff from decaying organic matter such as leaves and grass will yield coliform bacteria.

The coliform group comprises all of the aerobic and facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C. This definition of coliform group is equivalent to the "B. coli group" and to the "coli-aerogenes group" expressions utilized by many individuals. The standard test for the coliform group may be carried out either by the multiple-tube fermentation technique, presumptive test, confirmed test, or completed test) or by the membrane filter technique - each technique being applicable within the limitations specified and with due consideration of the purpose of the examination. As applied to the membrane filter technique, the coliform group may be redefined as comprising all the aerobic and facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria which produce a dark colony with a metallic sheen within 24 hr on an Endo-type medium containing lactose.

The multiple tube fermentation technique or most probable number (MPN) analysis is one of the crudest quantitative methods for enumerating the number of bacteria in a water sample. The MPN technique is a statistical count based on the probable number of bacteria growing in several tubes in a series of serial dilutions. In coliform analysis it has been the practice to use the five-tube, three-dilution method. The ability of the coliforms to ferment lactose is used as the indicator for presence of coliforms. In the lactose broth tubes an inverted vial is inserted to trap the gas resulting from the lactose fermentation. Usually, five tubes of lactose broth are inoculated for each of three serial dilutions and incubated for 24 hr at 35°C. Often it is necessary to set up four or five serial dilutions to get three serial dilutions with valid results. The production of gas is considered presumptive evidence of coliforms. The MPN value is calculated from standard statistical tables.

The MPN value is not an absolute number, but it has been so abused by sanitary engineers that the MPN value has almost taken absolute significance. A single MPN value suddenly becomes an absolute number. The most apparent symptom of the absoluteness of the MPN value was in an evaluation study of the membrane-filter technique for coliform analyses. Some microbiologists felt the membrane-filter technique was not good because it failed to reproduce the MPN value. Actually, the membrane filter is the more accurate of the two methods. Although the method is not precise, the MPN has been used for a large number of years and has yielded results which are satisfactory for proper sanitary control. In spite of its inaccuracies and the large number of tubes required, the MPN method is not going to be immediately displaced for coliform analyses because of individual agency preference. Therefore, in order to utilize available data, it may be necessary to incorporate the results of collateral MPN results into a sampling program for urban runoff.

The membrane filter has opened up entirely new areas of quantitative microbiology, but it is far from a complete answer. Considerable controversy has raged in the field of sanitary microbiology over the membrane filter and its use for coliform analyses. It is not a simple or an easy technique, but rather a complex one requiring special equipment and a high operating cost. In the membrane filter technique the bacteria are filtered from solution onto the surface of a cellulose acetate filter. The filter is then placed on an absorbent pad containing the necessary nutrients in a special plastic petri dish. The plate is incubated for 24 hr and then counted. The membrane filters usually have a grid printed on them for ease of counting. Most sanitary microbiologists who run only a few bacteria counts a day do not like the membrane-filter technique, while those who run a large number of analyses would not have anything else. The reason for this lies in the preparation of media and petri dishes. In an effort to simplify the procedures and make them more attractive to the small user, the manufacturers provide kits which contain a sterilized petri dish, a sterilized nutrient pad, and sterilized media. Once the test has been run, the petri dish and filter are discarded. The cost of the complete kits is high by comparison with other methods, but the time saved in preparation and cleaning up justifies the additional expense. As more prepared media and simplified techniques become available, the membrane filter will be used more and more. The membrane filter works best on a very dilute sample and is designed to pass a relatively large volume of water through the filter to give uniform distribution.

Elevated temperature tests for the separation of organisms of the coliform group into those of fecal origin and those derived from nonfecal sources have been used in many parts of the work and with various modifications. Recent modifications in technical procedures, standarization of methods, and detailed studies of members of the coliform group found in the feces of various warm-blooded animals compared with those from other environmental sources have established the value of a fecal coliform determination. The test may be performed either by multiple-tube procedures or by the membrane filter method. Either procedure will yield adequate information as to the source of the coliform group (fecal or nonfecal) when used as a confirmatory test procedure. The fecal coliform test is applicable to investigations of stream pollution, raw water sources, sewage treatment systems, bathing waters, sea waters, and general water-quality monitoring. The procedure is not recommended as a substitute for the coliform test in the examination of potable waters, since no coliform bacteria of any kind should be tolerated in a treated water.

For the purposes of an urban runoff quantification program, a pathogenic indicator is a definite requirement because of the potential presense of illegal connections and discharge of sanitary sewage into the runoff drainage networks. At the present time, the fecal coliform indicators are the superior methods for assessing the sanitary quality of stormwater flows. While careful laboratory techniques should be exercised, it is apparent that with the normally high bacterial counts encountered, high precision is not required and would be an unnecessary expense to attempt to effect. It has been suggested by the U.S.E.P.A. Office of Research and Development that the membrane-filter techniques be employed for conducting fecal coliform counts.

Eutrophic Potential. The eutrophication potential has probably received more attention in the last 15 years than any other water resource problem. Eutrophication is a natural process but man's activities can greatly increase the rate. At the present time the runoff eutrophication potential is best determined by the nitrogen and phosphorus concentrations of water bodies.

Throughout the centuries, the presense of organic matter such as plants and animals on the earth's surface has resulted in the enrichment of ground and surface waters by the addition of nitrogen and phosphorus forms. The productivity of natural waters in terms of algal growths is related to the fertilizing matter that gains entrance to them. Nitrogen in its various forms is a major consideration. Also, reduced forms of nitrogen are oxidized in natural waters, thereby affecting the dissolved-oxygen resources. For these reasons nitrogen data are an essential part of the information needed in stream-pollution-control programs.

The atmosphere serves as a reservoir from which nitrogen is constantly removed by the action of electrical discharge and nitrogen-fixing bacteria and algae. During electrical storms large amounts of nitrogen are oxidized, and its union with water produces dilute nitric acid which is carried to the earth in the rain. The nitrates serve to fertilize plant life and are converted to proteins.

Animals and human beings are incapable of utilizing nitrogen from the atmosphere or from inorganic compounds to produce proteins. They are dependent upon plants, or other animals that feed upon plants, to provide protein. Within the animal body, protein matter is used largely for growth and repair of muscle tissue. Some may be used for energy purposes. In any event, nitrogen compounds are released in the waste products of the body during life. At death the proteins stored in the body become waste matter for disposal.

Analyses for nitrogen in its various forms have been performed on potable and polluted waters ever since man became convinced that water was a vehicle for the transmission of disease. The determinations served as one basis of judging the sanitary quality of water for a great many years; however, nitrogen analyses today are performed largely for other reasons. Prior to the development of bacteriological tests for determining the sanitary quality of water (about 1893), sanitary engineers and others concerned with public health were largely dependent upon chemical tests to provide circumstantial evidence of the presence of contamination. The chloride test was one of these, but it gave no evidence of how recently the contamination had occurred. Chemists working with sewage and freshly polluted waters learned that most of the nitrogen is originally present in the form of organic (protein) nitrogen and ammonia. As time progresses, the organic nitrogen is gradually converted to ammonia nitrogen, and later on, if aerobic conditions are present, oxidation of ammonia to nitrites and nitrates occurs. The progression of events was found to occur somewhat predictably, and more refined interpretations of the sanitary quality of water were based upon this knowledge. For example, waters that contained mostly organic and ammonia nitrogen were considered to have been recently polluted and therefore of great potential danger. Waters in which most of the nitrogen was in the form of nitrates were considered to have been polluted a long time previously and therefore offered little threat to the public health. Waters with appreciable amounts of nitrites were of highly questionable character. The bacteriological test for coliform organisms provides circumstantial evidence of much greater realiability concerning the hygenic safety of water, and it has eliminated the need for extended nitrogen analysis in most water supplies.

Nitrogen is one of the fertilizing elements essential to the growth of algae. Such growth is often stimulated to an undesirable extent in bodies of water that receive sewage or treatment plant effluents, because of the nitrogen and other fertilizing matter contributed by them. Nitrogen analyses are an important means of gaining information on this problem. The autotrophic conversion of ammonia to nitrites and nitrates requires oxygen, and so the discharge of ammonia nitrogen and its subsequent oxidation can seriously reduce the dissolved-oxygen levels in rivers and estuaries, especially where long residence times required for the growth of the slow-growing nitrifying bacteria are available. Also, these organisms are produced in large numbers by highly efficient aerobic biological waste treatment systems, and their discharge with the treated effluent can cause rapid nitrification to occur in waterways.

Since the various nitrogen forms are of interest to engineers and planners, more than one analysis is necessary for quantification purposes. Regardless of the analysis performed, it is customary to report all results in terms of nitrogen so that values may be interpreted from one form to another without use of a factor. The classical Kjeldahl method determines organically bound nitrogen in the trinegative state. The organic nitrogen content of a water is contributed in various degrees by amino acids, polypeptides and proteins--all products of biologic processes--and thus includes albuminoid nitrogen. A rise in the organic nitrogen content may often be related to the sewage or industrial waste pollution of a given water supply.

The Kjeldhal nitrogen procedure converts nitrogen components of biological origin such as amino acids, proteins and peptides to ammonia, but may not convert the nitrogenous compounds of some industrial wastes such as amines, nitro compounds, hydrazones, oximes, semi-carbazones and some refractory tertiary amines. If ammonia nitrogen is not removed as described in the initial phase of the organic nitrogen procedure, the term "total kjeldahl nitrogen" is applied to the result. Should the total kjeldahl nitrogen and ammonia nitrogen be determined individually, the "organic nitrogen" can then be obtained by difference.

The U.S.E.P.A. Office of Research and Development has suggested that basically two nitrogen analyses be conducted. The first for total oxidized forms of nitrogens, that is, the sum of nitrite and nitrate. The second nitrogen analysis would be for the reduced forms of nitrogen. For this it is suggested that the Kjeldahl procedure be used. It is further recommended by E.P.A. that both oxidized and reduced nitrogen analyses be expressed in terms of weight of nitrogen rather than individual ions. This way, the two values for total nitrogen content can be added.

Phosphorous occurs in natural waters and in wastewaters almost solely in the form of various types of phosphate. These forms are commonly classified into orthophosphates, condensed phosphates (pyro-, meta-, and polyphosphates) and organically bound phosphates. These forms of phosphate may occur in the soluble form, in particles of detritus, or in the bodies of aquatic organisms.

The various forms of phosphate find their way into wastewaters, effluents and polluted waters from a variety of sources. Small amounts of certain condensed phosphates are used in some public water supplies as a means of controlling corrosion. They are also used in some softened waters for stabilization of calcium carbonate to eliminate the need for recarbonation. Additional quantities of the same compounds may be added when the water is used for laundering or other cleaning, since these materials are major constituents of many commercial cleaning preparations utilized by homeowners. Virtually all household cleansers such as Comet, Ajax, etc. contain from 10-15 percent trisodium phosphate plus perhaps additional phosphorus compounds that are carried from the household to the sewer system and potentially to receiving streams. Streams and lakes are also enriched by the runoff of orthophosphates from agricultural or residential lands where phosphate fertilizers are utilized.

All surface water supplies support growths of minute aquatic organisms. The free swimming and floating organisms, called plankton, are composed of animals (zooplankton) and plants (phytoplankton). The latter are predominately algae, and since they are chlorophyll-bearing organisms, their growth is influenced greatly by the amount of fertilizing elements in the water. Research has shown that nitrogen and phosphorus are both essential for the growth of algae and that limitation in amounts of these elements is usually the factor that controls their rate of growth. Where both nitrogen and phosphorus are plentiful, algal blooms occur which may produce a variety of nuisance conditions. Experience has shown that such blooms do not occur when nitrogen or phosphorus or both are present in very limited amounts. The critical level for phosphorus has been established as somewhere near 0.01 mg/l.

Domestic sewage is relatively rich in phosphorus compounds. Most of the inorganic phosphorus is contributed by human wastes as a result of the metabolic breakdown of proteins and elimination of the liberated phosphates. Organic phosphates are formed primarily in biological processes; hence, they are contributed to sewage in body wastes and food residues, or they may be formed from orthophosphates in biological treatment processes or by life in the receiving water. The amount of phosphorus released is a function of protein intake and, for the average person in the United States, this release is considered to be about 1.5 g/day,

The only inorganic compounds of phosphorus of significance in sanitary engineering practice are the phosphates or their molecularly dehydrated forms, usually referred to as polyphosphates. Organically bound phosphorus is usually a minor consideration.

Phosphate analyses embody two general procedural steps: a) conversion of the phosphorus form of interest to soluble orthophosphate, and b) colorimetric determination of soluble orthophosphate. The separation of phosphorus into its various forms is largely analytically defined, but the analytical differentiations have been selected so that they may be used for interpretive purposes.

Separation of "filtrable" (or "dissolved") from "particulate" forms of phosphate depends on filtration through a 0.45-µ membrane filter. The selection of membrane filtration over depth filtration is made because of the greater likelihood of obtaining a consistent separation of particle sizes by the membrane filtration technique. No claim is made that filtration through 0.45-µ membrane filters is a true separation of suspended and soluble forms of phosphate; it is merely a convenient and replicable analytical technique designed to make a gross separation. This is reflected in the use of the term "filtrable" (rather than "soluble") to describe the phosphorus forms determined in the filtrate which passes the 0.45-µ membrane.

The phosphates which respond to the colorimetric tests without preliminary hydrolysis or oxidative digestion of the sample are considered as "orthophosphate." Strictly speaking, a small fraction of any condensed phosphates present is usually hydrolyzed unavoidably in the procedure, and thus is reported as a part of the orthophosphate. Orthophosphates occur both in filtrable (dissolved) and in particulate form.

Acid hydrolysis at boiling-water temperature is designed to convert filtrable and particulate condensed phosphates to filtrable orthophosphates. The hydrolysis unavoidably releases some phosphate from organic compounds, but this factor has been reduced to a minimum (consistent with good condensed phosphate hydrolysis) by judicious selection of acid strength and hydrolysis time and temperature. Nevertheless, the term "acid-hydrolyzable phosphate"; is preferred over "condensed phosphate" for this technique.

The phosphate fractions which are converted to orthophosphate only by oxidative destruction of the organic matter present are considered "organic" or "organically bound" phosphate. The severity of the oxidation required for this conversion depends upon the form--and to some extent upon the amount--of the organic phosphate present. Like the orthophosphates and acidhydrolyzable phosphates, the organic phosphates occur both in the filtrable (dissolved) and in the particulate fractions. (2)

It has been recommended by the U.S.E.P.A. Office of Research and Development that total phosphorus analysis be conducted where impact on receiving water is of concern. In some investigations, it has been shown that analyzing for soluable phosphate alone can result in erroneously low conclusions. Therefore, it would be helpful to run both total soluable phosphate and total phosphorus analyses to achieve quantification.

Toxicants. In urban runoff, the presence of toxicants warrants special interest. Some toxicants can directly affect man (asbestos, lead, etc.) while others can have deleterious effect on the aquatic biota. For the purposes of discussion, toxicants can be put in the general categories of heavy metals, pesticides, herbicides and exotic chemical compounds.

Undoubtedly, no other class of pollutants is more controversial than toxicants. For enforcement, a potential pollutant must be rigorously defined as toxic by laboratory analyses or bioassays. Such analyses customarily expose an aquatic organism to greater and greater concentrations of a particular pollutant until a lethal dosage is evidenced. The discharger will usually contest the effluent limitations imposed if the bioassays were not conducted on the aquatic species unique to the receiving stream.

For bioassay work for example, the goldfish has been found to be a particularly useful test animal. Goldfish of any size up to six inches are easily obtainable in quantity from commercial goldfish farms, are relatively inexpensive, and stand shipment well. The practical considerations, although important in the selection of a test animal, are of course secondary to the physiological characteristics of the goldfish which made it particularly suitable for the bioassays of stream pollutants. By comparative tests the relative resistance of the goldfish to poisons, injury, and anosemia has been found to be equal to or greater than that of bass, perch or catfish, and definitely greater than the resistance of trout or most fresh-water minnows. The minimal lethal concentration of any effluent or pollutant for goldfish established, therefore, approximates the maximal concentration of that pollutant which ought not to be exceeded if any fresh-water fish were to survive in waters polluted with such effluent. Regardless of the above considerations of relative resistance to toxicants, it would undoubtedly be argued, however, that the goldfish is not indigenous to the Houston area's receiving streams.

A final complication to bioassay work is the potential synergistic effects of more than one toxicant present in the waters at the same time. Whereas a sublethal concentration of either of two or more toxicants may be within established water quality standards, the combined effect of the toxicants can produce biologically suppressive conditions.

The subject and impacts of toxicants are varied so as to preeclude discussion in this document. The list of chemical compounds or substances which are deemed hazardous in certain concentrations in stream waters numbers in the hundreds. Obviously, therefore, a sampling program could not prepare specific analyses for each substance for every water quality sample. In order to provide surveilance for this vast array of chemical toxicants, general test for categories of substances such as heavy metals, polychlorinated biphenyls, pesticides, etc. should be performed on samples at some frequency to detect substance presence; then analytical tests can be run to identify and quantify the specific parameter identified. Dependent on the land use changes or industries in the contributory watershed, the frequency of toxicant sampling could be from once every six months to once every two years. This frequency of course, should only be maintained until toxic substances are identified. After that point, sampling for the substance should be conducted routinely at the time the stream is normally monitored.

Of particular concern to water quality from a nonpoint pollution source standpoint is the presence of heavy metals. It is suggested that composite samples of runoff be run for lead, zinc, copper, chromium, mercury, cadmium, arsenic, nickel, and tin initially. Then, based on the results, a decision can be made on what and how often discrete or other composite analyses will be necessary. Certain industrial land uses can be circumstances where determination of uncommon parameters may be desirable. For heavy metals, evaluation of the toxic potential requires that the total amount of the heavy metal be determined. In some cases it may be necessary to determine the chemical form of a given heavy metal. Therefore, because of the organics present, samples should be digested prior to analysis.

Because of the controversy over pesticides and polychlorinated biphenyls, a waste treatment management agency might be urged to sample for these parameters; again however, these analyses are not recommended for routine analyses. If areas of potential contamination are identified by the above-mentioned periodic intensive analysis, the frequency and season for testing can be established.

Physical State. In addition to the above categories of pollutants and contaminants in runoff, there are a number of simple analyses which can be used to describe the physical state or conditions of storm discharges. These analyses include pH, temperature, conductivity, color, and odor. In addition to these tests, examination for asbestos, rubber, asphaltic materials, oils and grease, and sulfates can be significant on a site specific basis.

The pH of a water or wastewater is defined as the negative logarithm of the hydrogen ion concentration and is an index of the degree of hydrogen ion concentration or relative acidity. The pH of a sample is an electrometric measurement, using either a glass electrode in combination with a reference potential (saturated calomel electrode) or a combination electrode (glass and reference). The specific conductance of a water quality sample is measured by use of a self-contained conductivity meter, Wheatstone bridge-type device or equivalent. Samples are preferably analyzed at 25°C. If not, temperature corrections are made and results reported at 25°C. The specific electrical conductance of industrial wastewater, treatment plant effluents, and polluted water may give useful indications of the total concentrations of ionic solutes. In some types of waste, all or nearly all of the dissolved material is ionic.

Methods and equipment required for determining specific conductance are directly applicable to most wastewaters. Special attention may be required to obtain representative samples and to prevent fouling of electrode surfaces.

One of the most useful applications of specific conductance measurements to wastewater is through monitoring equipment which is commercially available. These instruments provide essentially continuous records or indications of the conductance of flowing streams.

Specific conductance can be recorded either by single-parameter instruments or by more elaborate monitors which also measure and record other variables such as dissolved oxygen, pH, and temperature of the stream. The sensor (or cell) may be placed in a tank through which water is pumped continuously, or placed directly in the flowing stream, depending on conditions at the monitor site.

The Platinum-Cobalt method is useful for measuring the color of water derived from naturally occurring materials, i.e., vegetable residues such as leaves, barks, roots, humus, and peat materials. The method is not applicable to color measurement on waters containing highly colored industrial wastes. The Spectrophotometric and Tristimulus methods are useful for detecting specific color problems. The use of these methods, however, is laborious and unless determination of the hue, purity, and luminance is desired, they are of limited value.

Although the odor of water is rarely a water quality constraint, it does impair the aesthetics. In waters tributary to water supply reservoirs such as Lake Houston odor can be a concern. In the usual analysis, a sample of water is diluted with odor-free water until a dilution that is of the least definitely perceptible odor to each tester is found. The resulting ratio by which the sample has been diluted is called the "threshold odor number". People vary widely as to odor sensitivity, and even the same person will not be consistent in the concentrations he can detect from day to day.

Therefore, panels of not less than five persons, and preferably ten or more, are recommended to overcome the variability of using one observer. Realistically however, as an absolute minimum, two persons are necessary: One to make the sample dilutions and one to determine the threshold odor.

Oils and greases are a particularly difficult group of contaminants to monitor for in water quality analysis. The family of pollutants can include all the relatively nonvolatile hydrocarbons, animal fats and waxes, grease, and other types of greasy-oily matters which do not volatilize at temperatures below 80°C. The definition of grease and oil is based on the analytical procedure used. The source of the oil and/or grease, the solvent used, and the presence of extractable non-oily matter will influence the material measured and the interpretation of results. The test is only recommended in concentrated urban environments or where suspicion exists as to the presence of illegal discharges of prohibited materials.

Sampling Site Location

The adequacy of a sampling program depends largely on the optimum selection of sampling sites. Both the program cost and its effectiveness in collecting samples representative of the character of sewer flows are seriously affected by the care exercised in site selection. Awareness of the general character of sewer flows and of flow modes in storm sewers and combined sewers, and knowledge of the variability of pollutant concentration, leads to an understanding of how best to select sites for sampling. A more complete discussion of flow regimes and the hydraulic difficulties of proper site selection are included in the introduction to the preceding section on Water Quality Characterization.

In the development of a system or network of flow measurement stations, primary consideration must be given to cost if the maximum benefit is to result from available funds. Therefore, cost must be considered in the selection of each gaging site. Cost reduction can result from selection of sites where the less expensive types of equipment, which will fulfill project requirements of accuracy and completeness, can be installed. For example, if a site is selected where conditions are such that satisfactory records can be obtained with a weir installation, this would be preferable to selecting a site where the head loss required by a weir would not be available, and the expense of installing a Parshall flume must be met.

A basic consideration in site selection is the possible availability of the flow measurements or records collected by others. At times, data being collected by the U.S. Geological Survey, by the State, or by other public agencies can be used. There are locations where useful data, although not currently being collected, may have been collected in prior years. Additional data to supplement those earlier records may be more useful than new data collected at a different site. Other general site considerations include any history of surcharging, entry and backwater conditions, and intrusion from receiving waters. (1)

Requirements that apply to all flow measurement sites are accessibility, personnel and equipment safety, and freedom from vandalism. If a car or other vehicle can be driven directly to the site at all times, the cost in time required for installation, operation, and maintenance of the equipment will be less, and it is possible that less expensive equipment can be selected. Consideration should be given to access during the period of adverse weather conditions and during periods of flood stage. Sites on bridges or at manholes where heavy traffic occurs should be avoided unless suitable protection for men and equipment is provided. If entry to enclosed storm sewers is required, the more shallow locations should be selected where possible. Manhole steps and other facilities for sewer access must be carefully inspected, and any needed repairs made. Possible danger from harmful gases, chemicals, or explosion should be investigated. With respect to sites at or near streams, historical flood marks should be determined and used for placement of access facilities and measurement equipment above flood level where this is possible. Areas of known frequency vandalism should be avoided. Selection of sites in open, rather than secluded, areas may help to reduce vandalism. Often, the only solution to prevent destruction of facilities is to place them in solid concrete or steel shelters, and to surround them with heavy fencing. Erection of warning signs is futile, as they often serve only to provide targets. (1)

Many of the considerations expressed for flow measurement are equally applicable to those for water quality monitoring, particularly with regard to maximum accessibility and safety. For closed systems, manholes on busy streets should be avoided if possible. Sites with a history of surcharging or submergence, should be avoided if possible; and again locations should be avoided which may tend to invite vandalism. An obvious important consideration for water quality sampling is that the site provide the information desired. In order to assure the collection of accurate information, substantial familiarity with the drainage and sanitary sewer systems is necessary. Knowledge of the existance of all sanitary and stormwater inflows to the stream segment between sampling points is essential. It is for this reason in this analysis that all known point source discharges in the Houston 208 Area were tabulated according to the water quality monitoring station to which it was tributary. The results of that inventory are presented in a later section of this report.

A sampling point for water quality quantification should also be for enough downstream from any tributary inflow to ensure complete mixing of the tributary with the main stream flow. In selection of a site an attempt should be made to locate the monitoring point in a straight length of sewer, at least six channel widths downstream from any bends to assure uniform velocity distribution.

As indicated in the introduction to the section on Water Quality Characterizations, one of the interesting contradictions in sampling site locations is that the site should be located at a point of maximum turbulence in order to assure complete mixing and homogenity of the sample. Again, maximum turbulence is not conducive to most commonly used technqiues of low measurement. In areas of greater topographical relief than Houston, sampling points could be located downstream from a drop or hydraulic jump. The methods of measuring flow which utilize a drop of hydraulic jump, however, also consume precious elevation and are not recommended for the Houston area.

In all cases of water quality characterization the cost of sampling site installation must be considered by balancing cost against effectiveness in providing the data needed. Frequently, the most obvious and most cost-effective sampling site for nonpoint pollutant source quantification is the one which has been in existance for other purposes of public health or enforcement. Such a site with a period of record can provide data to the agency concerned with nonpoint quantification at little or no additional cost to the program.

Because of access constraints on the physical constrictions in the field, there may be some situations where there is no choice of sites or only a single site may be available where an accurate flow measurement can be made. Typically, the ideal sites for flow measurement and water quality sampling will not be coincident and the problem becomes one of selecting the most suitable flow measurement or sampling equipment and methods for the available site. Equipment selection and capabilities are discussed in the next section of this report.

Equipment Selection and Capabilities

In general, the selection of the type of sample to be collected depends on a number of factors such as the rates of change of flow and of the character of the wastewater, the accuracy required, and the availability of funds for conducting the sampling program. All samples collected, either manually or with automatic equipment, are included in four types.

Samples Collected Manually or with Automatic Equipment.

1) Discrete Samples

These are samples that are collected at selected intervals, and each sample is retained separately for analyses.

2) Simple Composite Samples

These samples are made up of a series of aliquots (smaller samples) of constant volume collected at regular time intervals and combined in a single container.

3) Flow Proportional Composite Samples

These samples are collected in relation to the flow volume during the period of compositing, thus indicating the "average" waste condition during the period. One of the two ways of accomplishing this is to collect samples of equal volume, but at variable time intervals which are inversely proportional to the volume of the flow. That is, the time interval between samples is reduced as the volume of flow increases. Alternatively, flow proportioning can be achieved by increasing the volume of each sample in proportion to the flow, but keeping the time interval between samples constant.

4) Sequential Composite Samples

These samples are composed of a series of short-period composites, each of which is held in an individual container. For example, each of several samples collected during a 1-hour period may be composited for the hour. The 24-hour sequential composite is made up from the individual 1-hour composites.

Although the various types of composite samples are useful when an overall picture of "average" wastewater conditions is desired (e.g., monitoring industrial discharges, checking treatment plant efficiencies, etc.), they do nothing to describe the pattern of changes that may occur over the compositing period. Therefore, discrete sampling is generally more useful for stormwater characterization, since it allows pollutant parameters to be determined over a known time history and this provides information about their variability with time.

Discharge Measurement. Not all types of flow meters are suitable for measuring stormwater flows. In fact, the severe conditions and characteristics of these flows place a number of very stringent design requirements on flow measurement equipment, if it is to function satisfactorily in such an application. It should also be apparent that no single design can be considered ideal for all flow measurement activities in all storm flows of interest. Characteristics of the available sites, as well as the particular flows in question, make a device that might be acceptable for one location totally unsuitable for another. (3) Despite this, some equipment "requirements" in the form of primary design goals and some desirable equipment features in the form of secondary design goals can be set forth.

The following are considered to be primary design goals for equipment that is to be used to measure storm sewer flows: (2)

1) Range

Since flow velocities may range from 0.1 to 30 fps, it is desirable that the unit have a very wide range of operation; be able to automatically shift scales; or otherwise cover at least a 100 to 1 range.

2) Accuracy

For most purposes, an accuracy of ± 10% of the reading at the readout point is necessary, and there will be applications where an accuracy of ± 5% is highly desirable. Repeatability of better than ± 2% is desired in almost all instances.

3) Flow Effects on Accuracy

The unit should be capable of maintaining its accuracy when exposed to rapid changes in flow; e.g., depth and velocity changes in an open channel flow situation. There are instances where the flows of interest may accelerate from minimum to maximum in as short a time period as five minutes.

4) Gravity and Pressurized Flow Operation

Because of the conditions that exist at many measuring sites, it is very desirable that the unit have the capability (within a closed conduit) of measuring over the full range of open channel flow as well as with the conduit flowing full and under pressure.

5) Sensitivity to Submergence or Backwater Effects

Because of the possibility of changes in flow resistance downstream of the measuring site due to blockages, rising river stages including possible reverse flow, etc., it is highly advantageous that the unit be able to continue to function under such conditions or, at a minimum, be able to sense the existence of such conditions which would lead to erroneous readings.

6) Effects of Solids Movement

The unit should not be seriously affected by the movement of solids such as sand, gravel, debris, etc. within the fluid flow.

7) Flow Obstruction

The unit should be as non-intrusive as possible to avoid obstruction or other interference with the flow which could lead to flow blockage or physical damage to some portion of the device.

8) Head Loss

To be usable at a maximum number of measurement sites, the unit should induce as little head loss as possible.

9) Manhole Operation

To allow maximum flexibility in utilization, the unit should have the capability of being installed in confined and moisture-laden spaces such as sewer manholes.

10) Power Requirements

The unit should require minimum power at the measuring site to operate; the ability to operate on batteries is a definite asset for many installations.

The following are desirable Secondary Design Goals or features for flow measuring equipment, especially for use in a storm sewer application: (2)

1) Site Requirements

Unit design should be such as to minimize site requirements, such as the need for a fresh water supply, a vertical drop, excessive physical space, etc.

2) Installation Restrictions or Limitations

The unit should impose a minimum of restrictions or limitations on its installation and be capable of use on or within sewers of varying size.

3) Simplicity and Reliability

To maximize reliability of results and operation, the design of the unit should be as simple as possible, with a minimum of moving parts, etc.

4) Unattended Operation

For the majority of applications, it is highly desirable that the equipment be capable of unattended operation.

5) Maintenance Requirements

The design of the equipment should be such that routine maintenance is minimal and troubleshooting and repair can be effected with relative ease, even in the field.

6) Adverse Ambient Effects

The unit should be unaffected by adverse ambient conditions such as high humidity, freezing temperatures, hydrogen sulphide or corrosive gases, etc.

7) Submersion Proof

The unit should be capable of withstanding total immersion without significant damage.

8) Ruggedness

The unit should be of rugged construction and as vandal and theft proof as possible.

9) Self Contained

The unit should be self contained insofar as possible in view of the physical principles involved.

10) Precalibration

In order to maximize the flexibility of using the equipment in different settings, it is desirable that it be capable of precalibration; i.e., it should not be necessary to calibrate the system at each location and for each application.

11) Ease of Calibration

Calibration of the unit should be a simple, straightforward process requiring a minimum amount of time and ancillary equipment.

12) Maintenance of Calibration

The unit should operate accurately for extended periods of time without requiring recalibration.

13) Adaptability

The system should be capable of: indicating and recording instantaneous flow rates and totalized flows; providing flow signals to associated equipment (e.g., an automatic sampler); implementation of remote sensing techniques or incorporation into a computerized urban data system, including a multi-sensor single readout capability.

14) Affordability

The unit should be affordable both in terms of acquistion and installation costs as well as operating costs, including repair and maintenance.

Water Quality Sampling. In general, the commercially available automatic samplers have been designed for a particular type of application. In this report, however, they are being considered for application in a storm sewer setting. Because of the vagaries of such an application, it is altogether possible that a particular unit may be quite well suited for one particular application and totally unsuitable for use in another. The following 12 points should be considered in the selection of a piece of automatic sampling equipment. (3)

1) Obstruction or clogging of sampling ports, tubes and pumps.

2) Obstruction of flow.

3) Operation under the full range of flow conditions peculiar to storm sewers.

4) Operation unimpeded by the movement of solids such as sand, gravel and debris within the fluid flow; including durability.

5) Operation automatic (during storm conditions), unattended, self-cleaning.

6) Flexibility of operation allowed by control system.

7) Collection of samples of floatable materials, oils, and grease, as well as coarser bottom solids.

8) Storage, maintenance and protection of collected samples from damage and deterioration as well as the sample train and containers from precontamination.

9) Amenability to installation and operation in confined and moisture laden places such as sewer manholes.

10) Ability to withstand total immersion or flooding during adverse flow conditions.

11) Ability to withstand and operate under freezing ambient conditions.

12) Ability to sample over a wide range of operating head conditions.

The foregoing discussion of the elements of an automatic sampler can be viewed as equipment requirements. In addition to these requirements. In addition to these requirements, there are also certain desirable features which will enhance the utility and value of the equipment. For example, the design should be such that maintenance and troubleshooting are relatively simple tasks. Spare parts should be readily available and reasonably priced. The equipment design should be such that the unit has maximum inherent reliability. As a general rule, complexity in design should be avoided even at the sacrifice of a certain degree of flexibility of operation. A reliable unit that gathers a reasonable representative sample most of the time is much more desirable than an extremely sophisticated complex unit that gathers a very representative sample ten percent of the time, the other 90 percent of the time being spent undergoing some form of repair due to a malfunction associated wtih its complexity. (1)

It is also desirable that the cost of the equipment be as low as practical both in terms of acquisition as well as operational maintenance costs. For example, a piece of equipment that requires substantial cleaning after each operation is very undesirable.

The sampler should be of sturdy construction with a minimum of parts exposed to the sewage or to the highly humid, corrosive atmosphere associated directly with the sewer. It should not be subject to corrosion or the possibility of sample contamination due to its materials of construction. The sample containers should be capable of being easily removed and cleaned; preferably they should be disposable.

For portable automatic wastewater samplers, the list of desirable features is even longer. Harris and Keffer (1974) give a number of features of an "ideal" portable sampler which are based upon sampler comparison studies and over 90,000 hours of field experience. Included were:

1) Capability for AC/DC operation with adequate battery energy storage for 120-hour operation at 1-hour sampling intervals.

2) Suitable for suspension in a standard manhole and still provide access for inspection and sample removal.

3) Total weight including batteries: under 40 pounds.

4) Sample collection interval adjustable from ten minutes to four hours.

5) Capability for collecting both simple and flow proportional composite samples.

6) Capability for multiplexing repeated aliquots into discrete bottles (i.e., sequential composite).

7) Intake hose liquid velocity adjustable from 2.0 to 10 fps with dial setting.

8) Minimum lift of 20 feet.

9) Explosion proof.

10) Watertight exterior case to protect components in the event of rain or submersion.

11) Exterior case capable of being locked and with lugs for attaching steel cable to prevent tampering and provide some security.

12) No metal parts in contact with waste source or samples.

13) An integral sample container compartment capable of maintaining samples at 4 to 6°C for a period of 24 hours at ambient temperatures up to 38°C.

14) With the exception of the intake hose, capable of operating in a temperature range between -10 to 40°C.

15) Purge cycle before and after each collection interval; and sensing mechanism to purge in event of plugging during sample collection and then collect complete sample.

16) Capable of being repaired in the field.

A decision as to whether manual or automatic sampling should be employed involves more than just cost considerations. Experience has indicated that operator training is necessary if manual sampling is to produce reproducible results. Instances have been noted wherein two different operators were asked to obtain a sample at a particular site with no other guidance given. Analyses of samples taken at almost the same instants in the time have shown variances up to 50%. Other work conducted solely to compare manual sampling methods has indicated such discrepancies in results that suspicion must be cast upon manual methods which involve dipping of samples out of raw waste sources, and has raised questions regarding the suitability of such manual grab sampling as a yardstick against which to measure other techniques. It should be noted also that the collection of flow proportional composite or sequential samples can become quite tedious if performed manually at the sampling site.

The U.S.E.P.A. Office of Research and Development at the Atlanta Stormwater Conference stated the point most emphatically: (3) "An automatic liquid sampler is one tool of several that must be employed for the characterization of runoff. Grab or random samples have little application in storm-generated runoff."

The decision to use automatic sampling equipment does not represent the universal answer to wastewater characterization, however. For initial characterization studies, proper manual sampling may represent the most economical method of gathering the desired data. It is also prudent from time to time to verify the results of an automatic sampler with samples obtained manually. In this regard, because of the strict chain of custody procedures that can be exercised with manually collected samples, they can be used to support those data resulting from the use of automatic sampling equipment. It should be noted, however, that more use is being made of automatic samplers as time goes by, and this trend is expected to continue.

Because of the variability in the character of storm and/or combined sewage, and because of the many physical difficulties in collecting samples to characterize the sewage, precise characterization is not practicable, nor is it possible. In recognition of this fact, one must guard against embarking on an excessively detailed sampling program, thus increasing costs, both for sampling and for analyzing the samples, beyond costs that can be considered sufficient for conducting a program which is adequate for the intended purpose.

Existing Monitoring Program Review

Introduction

In the preparation of the Greater Houston 208 Program Water Quality Data Base, the City of Houston Health Department developed a review of the currently active water quality monitoring programs in the study area. The Health Department draft report has been submitted to H-GAC and is available as Appendix C for additional reference. This section of the sampling Program Development Report will attempt to:

1) Briefly summarize the active quality water monitoring programs which could be considered significant from a nonpoint pollution source standpoint, and 2) Critique the value of the existing programs for analyzing, predicting, and/or monitoring nonpoint pollution,

Existing Monitoring Programs

The currently active water quality monitoring network include the sampling programs of the Texas Water Quality Board, the City of Houston Health Department, the U.S. Geological Survey, and the U.S. Environmental Protection Agency. In addition to these programs, Rice University and the group known as Earth Awareness conduct special sampling programs in conjunction with their collegate and high-school educational programs.

It should be noted that all the currently active water quality monitoring programs are simply sampling programs whose scope is exclusive of many of the criteria stated earlier in this report for an optimumly designed nonpoint source pollution quantification program. Such requirements as time-sychronous data collection on rainfall, runoff, and water quality simply are not attempted by the current programs because of the amount of area which must be covered by the programs and the limited available funding. It thus is likely that no existing monitoring programs could alone be utilized to produce a nonpoint source sampling program and that such quantification could only come from expensive and intesive investigations on smaller, specific areas. The results of that data could then be extrapolated to other areas of similar soil, land use, and topographic characteristics.

Texas Water Quality Board Program. The T.W.Q.B. conducts the most extensive monitoring network of any local agency. According to the City of Houston Health Department (HHD) Summary (Appendix C), the T.W.Q.B. currently maintains 44 stream stations and 44 esturaine stations out of the local district office. Presently all stations are sampled quarterly, except for the stations on the Houston Ship Channel which are sampled monthly. According to the HHD summary, all samples are analyzed at the local U.S.E.P.A. laboratory with split samples shared by the T.W.Q.B. and E.P.A. The estimated cost of the T.W.Q.B. program was reported by the HHD as $1,000 per year per sampling station. The specific water quality sampling parameters for each station are detailed in the San Jacinto River Basin Plan as well as the HHD Report and are summarized in Appendix B.

The T.W.Q.B. program is primarily a management and regulatory tool to monitor point sources of pollution; as such, the infrequent pattern of grab sampling can provide a level of enforcement data that the State can afford to produce. As with all other local sampling programs, the T.W.Q.B. effort, while proportionate to the level of funding available, simply cannot meet the requirements of a sampling program for the monitoring, quantification, and prediction of nonpoint pollution sources. A sampling frequency of once every three months, no matter how many parameters are analyzed, can provide time-synchronous data on any temporal activity within a watershed. Inferences from the T.W.Q.B. program for nonpoint source analysis should be as general in scope as the level of detail provided.

As indicated in the San Jacinto Basin Plan, the T.W.Q.B. analyzes for fecal coliform only at non-estuarine stations and for total coliform only at estuarine stations. It would be useful for nonpoint source analysis if both analyses were conducted together with fecal streptococci.

City of Houston Health Department Program. In 1971 the City of Houston established a Water Pollution Control Division to function within the City Health Department. The routine monitoring programs now include laboratory analyses for all City of Houston wastewater treatment plants, sampling of permitted industrial wastewater outfalls, and the six major bayous including inflows to and the water quality of Lake Houston.

The HHD maintains a monthly sampling frequency of its monitoring stations and performs chemical, biological, perticide, and sediment analyses as indicated in Table I-E-03 of the San Jacinto Basin Plan. From an analysis of the Houston 208 Program Data Base, it appeared that the City of Houston Health Department monitoring records were lacking in an estimate of stream discharge coincident with the water quality data. While the stream discharge may be less important to the public health that the HHD is charged with protecting, it is a critical stream parameter to nonpoint source quantification. Without discharge, stream load cannot be calculated nor can a water quality condition be attributed to an upstream contributing factor such as land use or discharge.

According to the Water Data Base, many of the HHD monitoring stations are sampled for only carbonaceous oxygen demanding substances and fecal coliform. Those sampling parameters are in keeping with the responsibility of the HHD to monitor inflows to Lake Houston. According to the monitoring program summary prepared by the HHD, the Department also samples for total coliform at all monitoring stations. Such data, although not currently inventoried in the Water Data Base would be useful for future nonpoint pollution source analysis. The inclusion of fecal streptococci data would also be useful, but again, little is useful without an estimate of the coincident discharge.

U.S. Geological Survey Program. The U.S. Geological Survey (U.S.G.S.) currently maintains in the area a water quality and flow monitoring program which is tended on a monthly basis. During the field data gathering, flow and rainfall measurements from permanently installed recording gages are collected and water quality grab samples are obtained. Field teams test for D.O., temperature, and conductivity in the field and return samples to laboratories in Houston or Austin for B.O.D.(5) and bacterial analyses. Other sample portions are frozen and shipped to the U.S.G.S. central laboratory to test for inorganic materials.

At the time the grab sample is taken, a measurement of instantaneous discharge is performed. Such data on discharge is valuable to a nonpoint analysis, but is unfortunately lacking in temporal scale which could provide an estimate of total stream load from nonpoint sources. A grab sample, no matter how well performed, can be representative only of the one instant of time during which the sample was taken. However, because many of the U.S.G.S. monitoring stations for discharge provide a continuous record of stream flow, those stations are invaluable for anymore intensive water quality monitoring programs in support of nonpoint source analysis.

Other Sampling Programs. In addition to the water quality monitoring programs sponsored by the above agencies, certain special projects or purposes have generated intense water quality monitoring programs on certain areas for short periods of time. Most notably in this category were the Galveston Bay Project and the E.P.A. - sponsored research at the Woodlands Development by Rice University and others. The Galveston Bay Project was a special water quality program from 1967 through 1974 which was funded by the Texas Water Quality Board and the U.S.E.P.A. The intensive sampling effort for that study was conducted from July 1968 to August 1972. Thirty-five monitoring stations were established during the initial phase of that study and six were added during the sampling phase. Although the overall success of the Galveston Bay Project may be questioned by a few, at least from a scientific standpoint the study was successful in its defined role of attempting to define causal relationships between instream water quality and pollution sources - a limiting factor in all other active water quality programs because of a lack of funding.

The notable E.P.A.-sponsored research at the Woodlands Development Project was designed to determine the water quality impact of a federally-subsidized development project whose objective was to minimize offsite water quality impact and attenuate developed surface water runoff flows. The project team of Rice University personnel and students and consultants collected and analyzed grab and composite samples during dry weather conditions as well as during storm events. Routine sampling was conducted on a bi-monthly basis and the E.P.A. SWMM model was exercised to calibrate it for the Woodlands watersheds. Projects such as this specific program are of the nature required for nonpoint quantification, although more intensive sampling would be required over a longer period of time. The investigations conducted at the three monitoring stations in the Woodlands were estimated to cost two to three times the total annual cost of the entire T.W.Q.B. monitoring program in the Houston area. Such expenditures, if extrapolated to many other land use-soil type conditions of interest would be an impossible burden to finance.

In 1970 a nonprofit educational advisory organization, Earth Awareness Foundation, was created to assist and work with various public awareness of environmental issues. In this effort, the Foundation selects approximately thirty students to work twelve weeks each summer in an environmental survey and research program to study and record existing water conditions at forty monitoring stations in the Clear Creek Basin. From the number of samples analyzed and the number of stations, it appears that the Earth Awareness program samples on a one-week frequency or more intensely than any other monitoring program in the Houston area. The primary disadvantage of the program, of course, is that it can't be operated year-round because of student availability. Another minor disadvantage of this program as well as any other short-term investigation is quality control, laboratory procedures, sampling methods, and overall repeatability of results. Because this program and the Rice University Woodlands project are also training efforts for students to learn sampling and laboratory procedures, it must be expected that some problem may occur in statistically blending the results of their efforts with those of the T.W.Q.B. and U.S.G.S. which are collected by full-time trained personnel.

In addition to the above sampling programs, the Galveston County Health District routinely monitors 118 sampling points within their jurisdiction. Monthly samples are collected at 33 stations, bimonthly samples are collected at 82 stations, and quarterly samples are taken from the remaining three stations. In addition to physical and chemical characteristics of the sample, the District records important collateral data on current and recent meteorological conditions. At the present time, the District's water quality data is not included in the Water Data Base prepared for the Greater Houston 208 Program.

Recommended Sampling Program and Implementation

Introduction

From a review of the currently active water quality monitoring programs, it is apparent that no single program has the funding, scope, or sampling density to be effective in an effort to quantify the

the impact of nonpoint sources of pollution. Each of the existing major sampling programs of the T.W.Q.B., City of Houston Health Department, and the U.S.G.S. are designed to perform the tasks unique to the enforcement, public health protection, or monitoring responsibilities of the respective agencies. As such, and because of a general lack of funding or past public desire for these agenc to expand their efforts to encompass nonpoint sources of pollution, the existing data base is not useful for a statistically reliable quantification of the land use-water quality relationship.

In a sense, periodic water quality sampling programs are similar to weather monitoring. It is only through an intense sampling of current conditions and the application of sophisticated three-dimensional mathematical models that prediction capability can be obtained. Similar intense water quality sampling is not performed for the general Houston area and therefore quantification is severly hindered and prediction is statistically unreliable.

The most serious difficulty with using the existing monitoring systems within the Houston 208 Area for nonpoint analysis is the nonhomogeneousness of the upstream contributory watersheds. Houston's lack of zoning, perhaps a stimulus to its continued growth, has yielded few areas of homogeneous land use within the more concentrated urban areas of the city. This mix of residential, commercial, and occasional industrial land use types in areas upstream of many monitoring stations makes the task of developing land use-water quality relationships a technical impossibility.

In the City of Houston Wastewater Management Plan published in 1974, approximately 400 sanitary sewer overflows were identified within the metropolitan area served by the Houston treatment facilities. During the storm events that produce nonpoint pollution, the sanitary sewers are simultaneously surcharged wtih excessive amounts of infiltration water. The infiltration results in the overflows which add to the pollution load carried by the streams and measured at the monitoring stations.

As stated throughout this report, existing water quality monitoring programs are not being reviewed for their ability to perform their primary function of providing data to the respective sampling agencies. The programs are being reviewed as to their ability to be incorporated or modified wholly or partially into a sampling program capable of identifying and quantifying nonpoint pollution sources. In this regard, it is an underlying presumption that only event-type sampling can be effective in the quantification of nonpoint sources.

If it is assumed logically that stormwater runoff or nonpoint pollution of a noncontinuous nature will only occur during or immediately after a rainfall event, it can be statistically calculated how many of the routine grab samples taken by the sampling agencies will be coincident with the rainfall event and useful for nonpoint analysis. If the ratio of the number of samples per year at a monitoring station to the number of days in a year is multiplied by the annual average number of rainfall-runoff event-days in the Houston area, the result will be the probable number of water quality grab samples per year that were taken during a period of runoff. For monthly or quarterly grab samples, this probable number is usually one or less.

Assuming that a researcher wasn't discouraged by having to quantify nonpoint sources with only one or two grab samples per year at each sampling site, the quantification is made substantially more difficult if an estimate of flow does not accompany the sample analysis or no indication is given whether the sample was taken before, after, or on the peak rate of runoff or during the time of maximum pollutant concentration. It is for these reasons that this report strongly concludes that only event-type continuous sampling of an intensive nature, as was done in the Woodlands-Rice project, can be effective in a program of nonpoint pollutant identification.

It is a further assumption of this report that the key to nonpoint quantification is the development of acceptable land use-water quality relationships. It was for that reason that one of the first efforts of this investigation was to combine for the first time the mapping efforts of the H-GAC staff with regard to land use, point sources of discharge, and all water quality monitoring stations. If land uses and point discharges impact the water quality observed at the monitoring stations, then such a working map could provide insight into the analysis results of the sampling points. Because of the amount of detail such a map entails, it is not reproduced with this report but is available from the H-GAC staff to interested individuals. In addition to land use and point discharges, the supporting soil types which underlie the land uses and are cut by the stream channels also substantially impact stream quality through bed and bank scour. As mentioned previously, the sanitary sewer overflows within the City of Houston collection system also have substantial impact on stream water quality during runoff events. The inclusion of these two additional items of data on the base map would have made the reference impossible to use because of the 'busy' nature of so many map variables. Instead, the Harris County Soil Survey and the 1974 Houston Wastewater Management Plan were used as references to assest in the recommendations included in this report.

In an effort to quantify the upstream loadings as a result of point source discharges, an attempt was made to inventory all point source discharges upstream of each water quality monitoring station. That inventory, included as Appendix A of this report, included both permitted and actual flow and waste characteristics of all discharges for which effluent data were available from the 1976 T.W.Q.B. printout of self-reporting data. It should be noted that the tabulation is incomplete and that although discharges are listed in an upstream manner as taken from the mapping program, the river mile location may indicate that the discharges are out of sequence. The rectification of these inconsistencies in the data files was far beyond the scope of this report and can potentially be resolved by the point source analyses and segment planning which is to follow in the 208 Planning Process.

Recommended Nonpoint Source Sampling Program.

1) It is recommended that no additional funding be expended to intensify the existing system of grab sampling in the H-GAC area for the purposes of nonpoint source monitoring. It is concluded that doubling, tripling, or increasing ten-fold the sampling frequency of the existing programs would not significantly improve the statistical reliability of these efforts with regard to their usefulness in nonpoint pollution source quantification.

2) Any effort or expenditure for nonpoint source quantification sould be directed only to event sampling of areas of uniform land use and soil characteristics or to areas of changing land use when that particular water quality impact is of interest.

3) A nonpoint source sampling program would require an organization and structure capable of substantial expansion and contraction in staff size without excessive cost. In this regard, it is recommended that any program of intensive sampling be conducted with the aid and assistance of the local university environmental studies programs. As has been evidenced in many water quality programs, student labor can provide a ready supply of relatively inexpensive labor. To avoid problems of repeatability and to assure quality control, the student efforts should be monitored by faculty personnel and by laboratory and analysts from the local T.W.Q.B. and U.S.E.P.A. offices. In addition to quality control, university faculty personnel could provide a management function and a coordination effort for the student labor.

4) It should be unnecessary to create any additional, special purpose organization simply to monitor and quantify nonpoint sources of pollution. It would be far more efficient to expand or draw upon the combined resources of the Houston Health Department, H-GAC, T.W.Q.B., E.P.A., and other local organizations than it would be to create an overlapping, duplicative structure. In this manner, any specially funded investigation could draw upon the funding

management, computer capability, and data processing skills of the H-GAC personnel, could tap the universities for a ready supply of concientious labor, and could utilize the laboratory and sampling facilities of the Houston Health Department, the T.W.Q.B., and E.P.A. If time-synchronous, flow-weighted, discrete sampling were conducted for storm events, the number of samples to be analysed and the simple glasswater requirements would thoroughly tax any single laboratory. If all the laboratories were utilized, including perhaps those at the universities, the sampling could be absorbed without undue need for expansion or creation of new facilities. The need for multi-lab useage would necessitate that quality control be affected by one of the participating agencies.

5) It is not recommended that stormwater sampling be conducted in the heavily developed portions of the City of Houston in areas where sewer overflows occur. Such overflows or mixes of land uses and densities can only confound the most exhaustive sampling program. It would be far better to defer such sampling until after the City of Houston accomplishes its wastewater collection system revitalization. Until then, those areas should only be sampled in such a manner that the upstream and downstream loads are quantified and the resultant charge is ascribed to the broad classification of "inadequately sewered, mixed useage, urbanized area".

6) Any nonpoint source quantification program should attempt to utilize data collected from other sources than mentioned herein for discrete land use types. For example, in the Ship Channel area where industries have been required to install stormwater collection and treatment facilities, effort should be made to obtain the influent and effluent data of these industries for use and extrapolation to similar areas in other locations. One complication to that data may be the excessive levels of atmospheric particulates in the general Ship Channel area. While atmospheric pollution can be primarily from point sources of exhaust, the impacts of fallout occur in a nonpoint manner. Thus, a particular land use type or industrial activity may be relatively 'clean' from a nonpoint source generation standpoint, but may have runoff water quality problems simply because of atmospheric fallout over which the land use or industry has no reasonable control.

7) Because of the cost, labor, and effort necessary to establish a stream flow discharge rating for a monitoring point, it is recommended that any nonpoint sampling program include as monitoring points the U.S.G.S. or Texas Water Development Board flow gaging stations in the area of interest.

8) Because of the prior investment in the quantification of runoff from the Woodlands Development, it is recommended that any

nonpoint source quantification program include a continuance of the work done there as an effort to quantify the impact of those land uses in a forested area on those characteristic soil types.

9) In a quantification program it is recommended that the number of land uses to be evaluated for impacts be restricted to a very few and no more than three-four at any one time such that the number of combinations of variables do not exceed the ability of the researchers to statistically evaluate. The U.S.E.P.A. is currently funding a nonpoint source program conducted by a group of Maryland University instructors. That group, called the Chesapeake Research Consortium is attempting to quantify the impact of five separate land uses on five watersheds through the use of five simultaneous loading equations. This type of analysis is currently the highest state of the art of nonpoint pollution quantification and would be recommended for any future effort in the Houston area.

10) Any water quality monitoring program for nonpoint sources of pollution must have corresponding rainfall data of equal reliability or the development of pollutant load-rainfall relationships will not be possible. The U.S.E.P.A. has published the recommendation of the consultants who developed the Stormwater Management Model that the rain gage density for nonpoint quantification and model calibration efforts should be, as a minimum, four per square mile. Considering that the current rainfall monitoring network in the 208 Study Area consists of only a handful of stations in thousands of square miles, such a desired density may seem excessive, but in consideration of the number of water quality monitoring points that would be necessitated, the requirement is not so unreasonable. The collection of water quality data without corresponding rainfall and runoff data would be a futile exercise.

11) Upon evaluation of the H-GAC land use maps for the projected time periods through year 1995 as overlayed over the working base map of existing land use, point source discharges, and water quality monitoring stations of the various agencies, the following recommended sampling locations are proposed for consideration in any future intensive sampling programs:

a) The general land use upstream from U.S.G.S. Station number 8068750 is exclusively agricultural with only scattered residential units. The projected land use data indicates that there will be no significant change in land use throughout the planning period to 1995. It is recommended that this station be included in any quantification effort as a baseline water quality condition for the urbanizing watersheds in the northern areas of the Houston Metropolitan area. Station 8068750 is located on Cypress Creek at Highway 290.

b) Just south of the Woodlands project on Spring Creek near Interstate 45, the land use projections indicate a continual intensification of land use to residential tracts over the planning period. That projected growth area is immediately upstream from the coincident monitoring stations of the U.S.G.S. (806850), the T.W.Q.B. (1008.01), and the Texas State Health Department (160606). Because of the ready access of this site to the freeway and the existance of the three stations, this site should also be included in a nonpoint source monitoring program. It should be noted that the area upstream from this projected development has already experienced some development and along Spring Creek there are a number of existing point source discharges. These discharges and the upstream nonpoint contributions should be quantified during the analysis by the taking of coincident upstream and downstream samples. This sampling site could provide data on the impact of land use change in the northern watersheds.

c) Although it would be of significant interest to establish an intensive nonpoint source monitoring program in the northeast quadrant of the H-GAC 208 Area in the vicinity of Lake Houston, the major tributaries carry at that point such substantial cummulative loads that nonpoint quantification would be impossible. The U.S.G.S. stations on Luce Bayou could provide data on the loads from relatively undeveloped forested areas and the impacts on Lake Houston could be estimated from the quantifications conducted on Spring and Cypress Creeks.

d) Within the southeast quadrant of the H-GAC Study Area lies the Houston Ship Channel which receives the effluent from perhaps 50-60 wastewater treatment facilities as well as the runoff from the greater portion of the metropolitan Houston area. Because of the endless complexities involved with any future quantitative assessment of the nonpoint loads to the Channel, any attempts at quantification should be kept as simple as possible such as attempting to gain a mass balance between the observed loads from all point sources and observed downstream water quality. Even a simple analysis such as this however would require the real-time processing of substantial quantities of data from diverse sources.

e) Also within the southeast quadrant of the study area is the Clear Lake watershed and other sensitive environmental areas. It is expected that development pressures will continue in these areas as the price of raw and developed land in the southwest, west, and northwest continues to escalate. Since the soils and native ground cover of the southeast areas is somewhat different from that which would be measured in a quantification effort in the Spring and Cypress Creek watersheds, it would be useful to select a developing area in the vicinity, establish a flow and water quality monitoring station, and begin to sample for a background level of pollutants from the native vegetation or existing land use. This project would be an ideal task in the quantification effort for the Earth Awareness group which is headquartered in that area. No specific sampling location is recommended at this time since there are no currently 'uncontaminated' water quality monitoring stations in the vicinity.

f) Within the southwest quadrant of the Study Area, the land use projections indicate a continual filling in of the area between an extension of Westpark, the Southwest Freeway, and the Harris County line. The projected development appears to be predominantly single family usage or a continuation of the existing trends in the area. Any quantification effort should include a monitoring of both the existing developments in the area as well as some undergoing change. Again, no specific sampling location is identified because of the homogeneous nature of the development pattern and the ready supply of available sites.

g) Within the Houston area, certain land use activities result in concentrations of impervious areas approaching 100 percent. Fortunately, many of these concentrations located outside of the downtown area are served by sewer systems which do not surcharge excessively during wet weather. In these areas, water quality sampling for intense commercial nonpoint source quantification can be affected. The shopping center located at Westbury Square is one such location and coincidently is one where Rice University has accomplished some initial stormwater sampling. In order to benefit from this prior work, it is recommended that any nonpoint quantification program include additional work at this site.

h) As stated previously, the age and inability of the sewer system in the downtown Houston area prevents the use of the area for the quantification of runoff from intensely developed commercial areas. The development of Houston has resulted in the construction of several 'Satellite' office parks in the suburban areas of the city which can be used for nonpoint source analysis. Two of the most intensely developed sites are those of the Galleria area and the Greenway Plaza complex. Although both of these projects were constructed in inadequately sewered areas, it is not believed that excessive surcharge exists within the sewer systems on the actual sites; therefore, relatively uncontaminated samples from essentially totally impervious areas of high traffic activity could be obtained. If time and/or money constraints prevent the sampling of both of these areas, then the Galleria area would probably provide a better sampling location because of the manner in which site drainage is accomplished there.

i) One of the common misconceptions in urban stormwater analysis is that there is a direct correlation between low-income and potential pollutant concentration in runoff waters. It should be noted that the correlation is not with regard to income levels but to the level of public service the area receives. In low-income areas the streets are in frequent disrepair and tend to remain so. Such a condition would not persist in wealthier or more influential areas of the city. As with any city, the level of service provided is proportional to the taxes paid by the residents regardless of what public policy may be. This allocation of services is therefore not unexpected, or necessarily unfair, it simply must be remembered in assessing causal relationships for nonpoint pollution source analysis. It is with these cautions in mind that the drainage area immediately south of W. Dallas and east of Taft Streets is recommended as a potential sampling site.

j) In the above recommendations, the development pattern of Houston is reflected in the recommendation for undeveloped forested areas, for single family residential development, for intense commercial and office park concentrations, for industrial sites in the Ship Channel area, and for central city areas of diminished public investment and service. The city is laced with another predominant land use in the form of multi-family dwellings of the apartment and townhome style. Although the city has a great many apartment sites and townhome areas for potential sampling of nonpoint sources, the complex located west of the West Loop and immediately south of Interstate 10 appears to be most ideally suited. The complex includes both multi-family apartment dwelling units to densities of 20-30 to the acre as well as more conventional townhomes in the order of seven-nine acre. The site is located close enough to outfall drainage that excessive ponding would not interfere with discharge measurements during frequent rainfall events and the site is readily accessible to all the sample analysis laboratories.

These sites can be noted on the Proposed Nonpoint Source Sampling Stations map enclosed in this report.

APPENDIX A

LOADING SUMMARIES

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day)					
				PERMITTED			ACTUAL		
				BOD	TSS	MGD FLOW	BOD	TSS	MGD FLOW
160606 ●	Spring Crk 1008	18.3	11303	25.02	37.53	0.300	0.08	1.24	0.009
8068500 ▲ 1008.01 □		19.0	10910	508.74	508.74	3.050	6.18	13.95	0.198
		19.0	11604*						
		19.0	11404	50.04	50.04	0.300	0.94	1.44	0.041
		19.0	11630*						
		32.0	10616	0.17	0.17	0.001	0.13	0.43	0.001
8068600 ▲	Spring Crk 1008	6.4	10908-02*						
		8.5/1.5	11463	8.34	8.34	0.250	0.18	2.03	0.014
		10.4	10908-01	83.40	83.40	0.500	5.53	14.89	0.192
		10.9/0.6	11572	3.67	3.67	0.022	0.40	1.67	0.015
8069500. ▲	Spring Crk 1008	0.0	11406*						
8068750 ▲	Cypress Crk 1009								

TWQB □
TSDH ●

USGS ▲
* Not found.

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	PERMITTED TSS	PERMITTED MGD FLOW	ACTUAL BOD	ACTUAL TSS	ACTUAL MGD FLOW
1067.09 ⊙	Cypress Crk. 1009	27.8	11084	125.10	125.10	0.750	35.02	95.23	0.356
		28.6/1.2	11336*						
		29.1/0.8	11454	8.34	8.34	0.050	1.55	3.01	0.028
			11506*						
		32.0/1.2	10876	83.40	83.40	0.500	22.01	98.71	0.333
		32.8	11267	50.04	50.04	0.300	1.40	3.85	0.061
		32.8/4.2	00960*						
		34.2	10962	25.02	25.02	0.150	5.36	7.34	0.081
		35.0/1.1	10867.02	10.84	10.84	0.065	4.86	3.85	0.051
		35.1/1.3	01402	——	——	——	33.37	1407.69	2.025
		38.7/2.2	11527*						
1009.03 ▣	Cypress Crk. 1009	5.3/2.0	11105	166.80	166.80	1.000	7.25	7.71	0.259

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day)					
				PERMITTED			ACTUAL		
				BOD	TSS	MGD FLOW	BOD	TSS	MGD FLOW
		5.6	11141	144.28	144.28	0.865	9.61	39.97	0.328
		5.0/3.4	11192	8.34	8.34	0.050	2.61	5.21	0.033
		20.2	11366	16.68	16.68	0.100	13.14	74.90	0.047
		21.2	11409	166.80	166.80	1.000	12.86	23.89	0.372
		20.7/3.2	11063*						
		21.3/2.4	11024	116.76	116.76	0.700	3.25	16.29	0.105
		22.0	10528	48.04	48.04	0.360	13.31	24.37	0.309
		22.0	10955	100.08	100.08	0.600	3.91	6.89	0.160
		23.4	11353*						
		26.4	11089	50.04	50.04	0.300	44.11	131.32	0.240
		26.5/1.6	11410	10.01	15.01	0.120	0.22	0.86	0.009
1009.02 □	Cypress Crk. 1009								

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	PERMITTED TSS	PERMITTED MGD FLOW	ACTUAL BOD	ACTUAL TSS	ACTUAL MGD FLOW
8069000 ▲	Cypress Crk. 1009	11.0	11239.03	16.68	16.68	0.100	4.18	5.78	✓0.024
1009.01 ■ 160708 ●		/1.2	10732	53.38	53.38	0.320	30.37	56.09	0.368
		/3.8	11081	238.56	238.56	1.700	54.70	73.65	0.884
		/3.6	11129	3.17	3.17	0.019	0.77	1.62	0.010
		/4.8	11215	23.35	23.35	0.140	4.13	11.33	0.057
		12.6	11314	8.34	8.34	0.050	1.91	11.08	0.040
			11237	12.51	12.51	0.075	0.07	0.03	0.001
		10.6/2.5	10903*						
1009.0050 ■	Cypress Crk. 1009	9.1	10783	66.72	66.72	0.400	11.28	22.11	0.167
		9.0/.6	11053*						
		10.0	11444	37.53	37.53	0.225	2.69	6.65	0.118
		11.8	10792	50.04	50.04	0.300	37.38	63.70	0.229

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day)					
				PERMITTED			ACTUAL		
				BOD	TSS	MGD FLOW	BOD	TSS	MGD FLOW
8069200 ▲	Cypress Crk. 1009	8.2	11142	50.04	50.04	0.300	14.56	37.01	0.159
		8.8	11044	35.03	35.03	0.210	13.95	34.04	0.101
16504 ○	West Fork San Jacinto River								
8068000 ▲ 1004.01 ▭	1004	NO DISCHARGES							
8069500 ▲	San Jac.West 1004	/.6	10928*						
160302 ○	San Jac.East 1003	10.0	11292*						
			11386*						
160010 ○	Lake Houston Dam 1001	/1.2	10668	16.68	16.68	0.100	5.54	14.17	0.061
8072000 ▲		4.5/3.7	10530	58.38	58.38	0.350	3.63	9.49	0.112
	Lake Houston 1006	3.6/2.5	11582	16.68	16.68	0.100	1.05	11.91	0.042
		6.0/4.5	11533	50.04	50.04	0.300	0.81	70.04	0.036
		6.3/1.7	11519	16.68	16.68	0.100	1.44	16.77	0.053

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	TSS	MGD FLOW	ACTUAL BOD	TSS	MGD FLOW
		.8	10495-82	50.04	50.04	0.300	19.03	33.79	0.221
		9.1/2.5	11518*						
		9/2.7	10826*						
		9/2.5	11167	8.01	8.01	0.048	—	—	—
	Lake Houston 1002	/2.7	11359*						
		/1.8	11059*						
		/0.2	10807	83.40	83.40	0.500	22.39	37.13	0.276
		17.7/3.5	11535*						
8072050 ▲	San Jac. 1001	.8/.7	11388	41.70	41.70	0.250	3.30	5.52	0.109
1001.02 ■			11329	75.06	75.06	0.450	8.22	54.55	0.269
			10541-02	36.70	36.70	0.220	8.46	12.28	0.106
1001.01 ■	San Jac. 1001	10104-01	125.10	125.10	0.750	698-26	704-93	0.830	

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day)					
				PERMITTED			ACTUAL		
				BOD	TSS	MGD FLOW	BOD	TSS	MGD FLOW
8072500 ▲	1007	0/.5	11124	1.50	1.50	0.009	4.98	7.91	0.451
		0/.9	11599	100.08	100.08	0.600	2.02	4.85	0.016
		0/2.8	11455	41.70	41.70	0.250	5.38	12.64	0.099
		0/4.0	11284	266.88	266.88	1.600	21.17	13.56	0.135
		3.8/4.0	11632	125.10	187.65	1.500	0.85	2.43	0.038
8072500 ▲ Cont.	1007	0/4.2	11290	112.59	168.89	1.350	40.79	163.89	0.275
		2.9/5.1	11152	166.80	166.80	1.000	60.96	67.24	0.579
		15	10706	125.10	125.10	0.750	12.28	22.31	0.403
8073500 ▲	1007	2.3/.5	10495-85	125.10	125.10	0.750	168.42	398.77	0.554
		3.3/.5	10495-86	83.40	83.40	0.5000	101.47	346.92	0.604
		2.5/1.2	01690	——	——	0.025	4.88	0.65	0.005
8073600 ▲	1007	0/2.0	01544*						

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	PERMITTED TSS	PERMITTED MGD FLOW	ACTUAL BOD	ACTUAL TSS	ACTUAL MGD FLOW
		.7/2.3	10559*						
		0/3.2	11330*						
8073700 ▲	1007	3.2	10495-30	2335.20	2335.20	14.000	1423.49	2062.22	15.624
8074000 ▲	1007	1	01851	—	—	0.005	0.23	1.40	0.007
		2.9/1.2	00357-01	—	—	0.350	—	48.83	0.309
		"	00357-02	—	—	—	—	—	0.317
		"	00357-03	—	—	—	—	—	0.281
		"	00357-04	—	—	—	—	—	0.235
		3.2/1.3	10495-29	3.50	3.50	0.021	11.59	9.04	0.045
		3.0/2.5	00687-01	—	—	—	41.51	49.75	0.036
		0/2.5	01197*						
		0/5.0	11207	83.40	83.40	0.500	21.19	27.48	0.370

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	PERMITTED TSS	PERMITTED MGD FLOW	ACTUAL BOD	ACTUAL TSS	ACTUAL MGD FLOW
		0/6.9	00797*						
8074500 ▲	1007	.6	11598*						
		1.9	01421*						
		3.7	01197*						
8074700 ▲	1007	.3	10495-01	9174.00	9174.00	55.00	44,592.✓98	100,745.✓13	82.223
		.9	00683	——	——	——	——	0.17	0.005
		2.2/1	01743-01	——	——	0.100	——	4.71	0.061
		——	01743-02	——	——	0.010	——	0.15	0.004
		3.2/.9	00785-01	——	——	——	1.14	1.25	0.015
8074700 ▲ Cont.	1007	——	00785.21	——	——	0.005	0.38	1.22	0.006
		.6	00312	——	——	0.500	——	——	0.153
1007.01 ▣	1007	.1	00635	——	——	0.722	83.90	128.08	0.804

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	PERMITTED TSS	PERMITTED MGD FLOW	ACTUAL BOD	ACTUAL TSS	ACTUAL MGD FLOW
		.3	00610	——	——	0.200	10.50	18.15	0.109
		.4	01021*						
		1	01036	——	——	0.075	2.05	2.87	0.037
		.4/.8	01061	——	——	——	——	——	3.600
		1.1/1	00427	——	——	0.250	65.64	13.28	0.154
1006.04 ■	1006	.3	00353	——	——	0.500	54.16	111.72	0.260
		.3	00733*						
		.6	00456	——	——	0.864	13.76	20.19	0.425
		1	00520-01	——	——	3.000	236.37	549.04	1.868
		1.5/.9	10495-10	125.10	125.10	0.750	85.70	196.37	0.734
		0/1.5	10831-02	16.68	16.68	0.100	24.73	26.53	0.111
1006.03 □	1006	.1	00786	——	——	0.065	6.98	7.97	0.072

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day)					
				PERMITTED			ACTUAL		
				BOD	TSS	MGD FLOW	BOD	TSS	MGD FLOW
		.2	01586*						
		.4	00638*						
		.8	01662*						
		.5	10831-01	116.76	116.76	0.700	189.00	192.20	0.723
1006.02 ▣	1006	.3	01159*						
		0/.7	01194	——	——	0.360	——	——	0.234
		.8	00815-01	——	——	3.150	210.86	341.59	2.408
		"	00815-02	——	——	0.030	1.87	2.40	0.016
		.8	00649-01	——	9007.20	21.600	——	5262.55	15.849
		"	00649-03	.5.67	8.51	0.034	1.03	6.73	0.038
		0/.9	00749	——	——	0.500	302.93	54.87	0.441
		1.2	00445	——	——	0.200	24.65	45.37	0.149

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day)					
				PERMITTED			ACTUAL		
				BOD	TSS	MGD FLOW	BOD	TSS	MGD FLOW
		.6/.5	00509-01	——	——	5.300	57.05	330.69	✓3.312
1006-02 ■ contd.	1006	"	00509-02	——	——	0.450	0.56	1.82	0.021
		"	00509-03	——	——	0.360	6.05	26.89	0.347
		"	00509-04	——	——	——	269.27	1272.88	11.879
		"	00509-05	——	——	——	——	33.02	0.102
		"	00509-06	——	——	——	——	11.35	0.053
		"	00509-07	——	——	——	——	——	——
		"	00509-08	——	——	——	——	——	——
		"	00509-09	——	——	——	——	19.22	0.011
		"	00509-10	——	——	——	——	——	0.003
		"	00509-11	——	——	——	——	63.31	0.142
		2.4	00541-01	——	——	0.600	4.26	64.59	0.315

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day)					
				PERMITTED			ACTUAL		
				BOD	TSS	MGD FLOW	BOD	TSS	MGD FLOW
		2.4	00541-02	—	—	0.250	2.04	49.14	✓0.055
		1.5	00839	—	—	—	—	0.20	0.006
		1.9	00671	—	—	0.155	17.91	18.93	0.103
		2.2	01745	1.17	—	0.007	0.10	1.19	0.004
		2.8	00413-01	66.72	133.44	0.200	0.63	1.83	0.016
		"	00413-02	—	—	—	0.13	0.53	0.003
		"	00413-03	—	—	—	0.11	0.45	0.011
		"	00413-04	—	—	—	0.17	0.51	0.018
		2.7	01308*						
		3.0	01849	—	—	0.144	6.65	15.46	0.043
		3.1	01740	—	—	44.000	8494.66	18832.10	44.659
		3.1	01034	—	—	0.003	3.65	3.37	0.123

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day)					
				PERMITTED			ACTUAL		
				BOD	TSS	MGD FLOW	BOD	TSS	MGD FLOW
		3.5/.3	00392-01	——	——	——	66.97	17.43	✓0.110
		"	00392-02	——	——	——	66.97	17.43	0.110
		"	00392-03	——	——	——	——	——	——
		"	00392-04	——	——	——	0.35	11.61	0.003
		"	00392-05	——	——	——	309.25	304.95	0.515
1006-02 ▣ contd.	1006	2.9/.6	01045	——	——	0.200	1756.85	2352.22	111.658
		3.6/.9	10053.01	500.40	500.40	3.000	878.52	723.77	2.475
		4/3.3	10053-05	667.20	667.20	4.000	856.24	809.69	2.511
		3.8	01032-01	——	——	441.000	——	——	121.909
		"	01032-02	——	——	0.007	0.05	0.19	0.001
		3.9	00574-02	——	——	——	——	——	0.178
		3.9	00547-03	——	——	——	——	——	0.238
1006.01 ▣	1006	.1	01707*						

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	PERMITTED TSS	PERMITTED MGD FLOW	ACTUAL BOD	ACTUAL TSS	ACTUAL MGD FLOW
		.5	01731	——	——	0.302	66.41	79.20	0.169
		.6	11127-02	0.33	0.33	0.002	0.04	0.03	0.001
		.8	01533*						
		.7	01247	——	——	0.050	1.82	1.58	0.010
		1.1	01205	0.33	0.33	0.002	0.19	0.21	0.001
		1.5/1	01310	——	——	0.200	7.31	15.57	0.073
		16	00458-02*						
		1.1	00305-01	——	——	12.000	——	191.93	5.676
		"	00305-02	——	——	105.000	——	5682.47	64.735
		"	00305-03	——	——	35.000	——	——	10.981
		"	00305.04	——	——	0.285	——	——	0.266
		"	00305.05	——	——	1.368	123.16	179.69	0.993

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day)					
				PERMITTED			ACTUAL		
				BOD	TSS	MGD FLOW	BOD	TSS	MGD FLOW
		1.1	00305-11	——	——	——	——	35.48	0.235
		1.2	00585*						
		1.4	01262-01	1.00	1.00	0.006	1.35	0.51	0.003
		1.9/.9	01860	——	——	0.007	0.10	0.14	0.004
		2.0/.5	00458-01	——	——	3.600	2108.69	3264.06	2.898
		1.1/1.6	001173	——	——	0.250	6.80	18.90	0.147
		1.1/1.4	00458-03*						
		2.0/1.3	00402-01	——	——	8.000	725.99	1599.19	7.259
1006.01	1006	2.2	00403-01	120.10	300.24	1.440	20.49	164.30	1.516
		"	00403-02	72.06	120.10	0.288	9.40	84.59	1.127
		"	00403-03	24.02	60.05	0.1440	9,40	84.59	0.684
		"	00403-04	48.04	192.15	0.576	14.35	73.87	0.302

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day)					
				PERMITTED			ACTUAL		
				BOD	TSS	MGD FLOW	BOD	TSS	MGD FLOW
		"	00403-10	1188.95	1981.58	4.752	420.70	425.80	3.178
		"	00403-12	1110.89	1666.33	2.664	182.18	246.89	1.859
		5	00492-01	613.82	920.74	3.680	285.43	3.783	228.23
		"	00492-02	—	—	4.750	221.86	753.83	4.137
		"	00492-03	0	0	8	158.75	285.90	2.651
		3.8	00002*						
		2.5/2.8	11127-01	1.83	1.83	0.011	0.14	0.15	0.003
		0/2.4	10184-01	10.51	10.51	0.063	21.17	19.44	0.094

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	TSS	MGD FLOW	ACTUAL BOD	TSS	MGD FLOW
		2.0/4.1	10854-01	2.17	2.17	0.013	2.60	2.34	0.014
2430.01 ■									
1005.02 ■	Tex. Park & Wld.Life 1006 San Jac	2.0	11214-01	1.67	1.67	0.010	0.10	0.15	0.006
	1005	0/1.9	01539	0	0	1.080	0	108.75	0.729
	1006	0/2.1	01429-01	—	—	—	—	—	—
			01429-11	0	0	1.282	0	0	0.782
			01429-21	0	0	0.110	0	0	0.009
	1005	0/2.1	00544-01	53.17	0	0.425	20.41	68.30	0.240
		0/2.9	00663*						
	City of Pas STP #2	0/1.9	10053-02	667.20	667.20	4	332.6	581.09	3.160
	(2427)	0/2.1	01785	0	0	0	2.23	17.61	0.051
2499.01 ■		.6	01206*						

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	TSS	MGD FLOW	ACTUAL BOD	TSS	MGD FLOW
	(2429)	.8	01215-01	——	——	——	——	——	——
			01215-02	——	——	——	——	——	——
		1.0	00540*						
2428.01 ■	Baytown Humble Docks	.4	10395-04*						
	(1005)	.5	01000-01	0	0	0.160	0	14.17	0.141
2427.01 ■	(2427)	2.0	00474-01	3336.00	3336.00	8	718.38	93.59	6.558
		3.6	00534-01	0	0	1.300	139.32	298.53	1.096
	(2427)	"	00534-02	0	0	0.430	24.15	72.70	0.204
		4.6	01280-01	0	0	0.350	41.90	16.59	0.186
		4.0	01026-01	0	0	0	0	0	564.061
2426.01 ■	(1005)	1.9	00592-01	0	0	25.650	1405.75	4475.34	20.218
	(1005)	"	00592-02	0	0	0	0	0	0

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	PERMITTED TSS	PERMITTED MGD FLOW	ACTUAL BOD	ACTUAL TSS	ACTUAL MGD FLOW
		2.0	01786	0	0	0	0.54	0.44	0.004
1005.01 ■	Morgan's Pt 1005	3.9	10779-01	16.68	16.68	0.100	2.30	3.47	0.056
		4.3	00440*						
	(2427)	3.6	01318-01	21.27	21.27	0.085	2.08	3.56	0.013
	(2425)	4.7	01220	——	——	——	——	——	——
	(2427)	2.7/3.0	11623-01	1.33	1.33	0.008	0	0	0.005
8074500 ▲	Parkglen MUD 1006	1.7	10906	333.60	333.60	2.000	8.78	17.03	0.476
		0/1.7	10852*						
		1.5/.9	01225	0	0	1.500	44.41	45.56	0.588
	Meadows MUD	2.4/.4	11039-01	145.95	145.95	0.875	14.50	35.17	0.354
		3.8	11128-01	400.32	400.32	2.400	32.18	16.67	0.575
		2.3/1.4	11088-01	83.40	83.40	0.500	3.46	14.38	0.133

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	PERMITTED TSS	PERMITTED MGD FLOW	ACTUAL BOD	ACTUAL TSS	ACTUAL MGD FLOW
		4.5	11461*						
		3.8/1.6	11019	58.38	58.38	0.350	23.43	47.70	0.492
		6.2/2.6	11599	100.08	100.08	0.600	2.02	4.85	0.016
		6.5/3.5	01853	0	0	0.475	4.86	8.78	0.336
8075000 ▲	Southside Place	.5	10712	36.03	36.03	0.216	24.08	24.42	0.103
	City of Bellaire	1.2	10550	750.60	750.60	4.50	311.01	67.935	2.154
	S.W. Plant	1.2	10495-37	5004.00	5004.00	30.00	1060.80	943.79	22.318
	WCID #94	9.0	10761	166.80	166.80	1.000	51.37	197.96	0.640
		9.8	11560*						
	Alief WCID #78	10.4	10157	108.42	108.42	11.94	20.77	0.287	
		11.2	11354	166.80	16680	1.000	0.81	1.41	0.043
		11.8	10832*						

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	PERMITTED TSS	PERMITTED MGD FLOW	ACTUAL BOD	ACTUAL TSS	ACTUAL MGD FLOW
		10.9	10495-44*						
1000.04 ■		1.0	00347-01*						
		"	00347-02*						
		6.0	01286	——	——	0.3000	3.72	9.44	0.124
	City of West Univ. Place	7.6	10058	166.80	166.80	1.000	270.53	203.30	1.261
			20372*						
	Sims Bayou Plant		10495-02	8006.40	8006.40	48.0	8883.74	16241.✓84	45.139
			00580-01	——	30.23	0.145	0.53	4.36	0.037
			00535-01	——	——	2.160	622.59	558.25	1.493
			00535-02	——	——	——	——	——	——
			00542	——	——	1.400	20.81	134.60	0.829
			01018*						

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	PERMITTED TSS	PERMITTED MGD FLOW	ACTUAL BOD	ACTUAL TSS	ACTUAL MGD FLOW
8075400 ▲	WCID #51	.5	01027-01	—	—	1.500	5.28	50.67	0.464
		1.1	10495-53	667.20	1000.80	8.000	158.01	121.62	2.716
	Subdivision Sewer Sys.	2.8	10934*						
		3.2	10960	1167.60	1167.60	7	92.37	139.46	0.587
		3.8	10570	108.42	108.42	0.650	20.32	30.46	0.211
		4.0	10495-69	216.84	216.84	1.300	92.67	67.33	0.716
		1.5/.8	10495-07	9.34	9.34	0.056	9.54	9.70	0.075
		4.1	01063*						
8075500 ▲		5.5	10495-47	200.16	260.63	0.250	260.24	447.29	0.483
		4.9	01788*						
		5.6	01211*						
		7.5	01538*						

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day)					
				PERMITTED			ACTUAL		
				BOD	TSS	MGD FLOW	BOD	TSS	MGD FLOW
	(1006)	7.9	01260	——	24.71	0.188	——	271.77	2.073
		6.3	00761*						
	Almeda Plaza	8.6	10495-03	224.79	38.90	1.333	2697.47	4570.82	15.996
8075650 ▲	City of S. Houston	.1	10287	204.16	204.16	1.224	80.11	140.29	2.128
		.3	01058	——	——	0.250	——	0.788	0.042
	City of Tomball	.9	11616	0.17	0.17	0.001	0.13	0.43	0.001
	(1006)	2.6	10495-65	35.70	35.70	0.214	125.24	156.92	0.428
		1.1	01688	——	——	0.006	0.92	1.68	0.004
8077000 ▲	Gulf Meadows Plant	.6	10495-20	41.70	100.08	1.000	116.26	198.07	1.498
		.4	11362*						
	WCID #44 PH. #3	4.7/2.3	10495-49	402.82	490.39	0.700	363.82	28.74	0.724
		8.7	01796*						

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day)					
				PERMITTED			ACTUAL		
				BOD	TSS	MGD FLOW	BOD	TSS	MGD FLOW
		10.9	01053*						
1102.01	City of Friendswood Plant #2	.1	10175-02	125.10	125.10	0.750	124.59	91.03	0.825
		.7/1.3	01571	——	——	——	——	——	0.360
		1.1/1.3	00951	——	——	0.300	11.92	12.58	0.233
	Sagemont MUD	2.2/1.3	10525*						
	S.E. Plant	2.0/8.2	10495-79	125.10	300.24	3.000	53.87	55.78	1.243
	City of Pearland Plnt. #2	7.5	10134-01*						
		8.7	10134-02	166.80	166.80	1.000	82.68	180.69	1.618
	City of Pasadena Landfill	0/6.0	10053-04	81.06	——	0.972	46.95	93.32	0.531
	Gulf Palms Plant	0/6.1	10495-21	48.04	94.58	0.180	137.17	133.34	0.324
	WCID # 47 (2425)	4.0/7.5	10495-50	500.40	500.40	3.000	112.33	66.75	1.495
		.8	0104402	0.07	0.13	0.001	0.05	0.11	0.001

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	PERMITTED TSS	PERMITTED MGD FLOW	ACTUAL BOD	ACTUAL TSS	ACTUAL MGD FLOW
	1.5	00808*							
	MUD #55 (1101)	2.8	11539	4.17	10.01	0.100	3.42	20.34	0.33
		4.5	11571*						
2425.02 ■		1.0	10243*						
	(2425) Taylor Lake WCID #75	2.4	10106	25.02	25.02	0.150	3.37	3.43	0.040
	Clear Lake City Water Authority	3.1	10539	187.65	450.36	4.500	39.73	118.83	1.971
		4.0	01728	——	——	0.090	1.55	4.90	0.071
	Nassau Bay PH #2	3.8	10526-02*						
	City of (1101) League City #1	4.2	10568-01	62.55	150.12	1.500	45.14	69.24	1.262
	(2425)	4.3	10568-02	6.26	15.01	0.150	9.95	17.13	0.278
2425.01	Kemah WCID #12	.9	10029	70.89	70.89	0.425	144.25	130.52	0.315
1104.01 ■	(1104)	4.3	10175-03	41.70	41.70	0.250	7.45	8.23	0.100

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	PERMITTED TSS	PERMITTED MGD FLOW	ACTUAL BOD	ACTUAL TSS	ACTUAL MGD FLOW
1103.02 ▣	(1003)	.3	00377	——	——	0.150	8.21	13.07	✓ 0.067
	Safari MHP	4.4	10861	10.84	10.84	0.065	4.86	3.85	0.051
	City of Dickenson Plnt. #1	1.1	10173-02	83.40	83.40	0.500	6.83	36.33	0.277
8077700 ▲	Alta Loma WCID #8	4.2	10174*						
		12	10005*						
		15	10629*						
		14.7	10420*						
2437.02 ▣	(1006)	.6	00535-01	——	——	2.160	622.59	55.25	1.493
		"	00535-02	——	——	——	——	——	——
		1.2	01485*						
		2.0	00451*						
		1.7	00944-01*						

MONITORING STATION	STREAM SEGMENT	RIVER MILE	W.C.O. NUMBER	EFFLUENT QUALITY (lb/day) PERMITTED BOD	PERMITTED TSS	PERMITTED MGD FLOW	ACTUAL BOD	ACTUAL TSS	ACTUAL MGD FLOW
		1.7	00944-04*						
		4.2	20592 *						
		4.4	00448-01*						
		"	00448-02*						
		3	00443-01*						
		"	00443-02*						
	City of La Marque	5.1	10410*						

APPENDIX B

TEXAS WATER QUALITY BOARD
AND
U.S. GEOLOGICAL SURVEY
MONITORING PROGRAM SUMMARIES

CURRENT TWQB MONITORING PROGRAM

The instream monitoring network represented in Table I-E-01 reflects the data available through the Texas Water Quality Board during the 1974 Fiscal Year.

"Type of Record" designations shown in Table I-E-01 are as follows: C denotes chemical parameters stations; P for pesticides in water stations; B for biological stations; and S for sediment sampling stations.

Chemical Stations (C)

a. Fecal coliform - at non-estuarine stations only-quarterly.

b. Total coliform - at estuarine stations only - quarterly.

c. Total phosphate, ortho-phosphate, ammonia nitrogen, nitrate nitrogen, chlorophyll "a", total suspended solids, volatile suspended solids, dissolved oxygen, temperature, pH, turbidity, conductivity, TOC, chloride, sulfate, TDS,quarterly.

d. Streamflow - at time of sampling.

e. Tidal measurements - quarterly in conjunction with estuarine monitoring (will use Corps of Engineers tide stage data if possible).

Pesticide Stations (P)

a. **Herbicides in water - annually.**

- **2,4 - D**
- **2,4,5 - T**
- **Silvex**

Sediment Stations (S)

a. **Herbicides in sediment - annually**

- **Silvex**

b. **Insecticides in water - annually**

- **Heptachlor**
- **Heptachlor epoxide**
- Lindane
- Malathion
- Methoxychlor
- Parathion

c. Insecticides in sediment - annually

1. Aldrin
2. Chlordane
3. DDD
4. DDE
5. DDT
6. Diazinon
7. Dieldrin
8. Endrin
9. Heptachlor
10. Heptachlor epoxide
11. Lindane
12. Methoxychlor
13. Methyl Parathion
14. Parathion
15. Toxaphene
16. PCB

Biological Stations (B)

a. Benthic macroinvertebrate communities - quarterly.

b. Before January 1, 1977, the following groups of organisms will be incorporated into the biological monitoring program:

  1. Plankton
  2. Periphyton
  3. Macrophyton
  4. Fish
  5. Shellfish

c. Tissue analyses - performed by the Texas Parks and Wildlife Department in cooperation with the U.S. Bureau of Sport Fisheries and Wildlife.

  1. Chlorinated hydrocarbons in coastal and inland waters semiannually.
  2. Metals in inland waters semiannually.

Sediment Stations (S)

The following will be measured annually:

a. Arsenic
b. Barium
c. Boron
d. Cadmium
e. Copper
f. Chromium (Total)
g. Lead
h. Manganese
i. Mercury
j. Nickel
k. Selenium
l. Silver
m. Zinc
n. Insecticides
o. Herbicides
p. Total Phosphate
q. Chemical Oxygen Demand
r. Kjeldahl Nitrogen
s. Volatile Solids
t. Oil and Grease

TABLE 1-E-01

TEXAS WATER QUALITY BOARD

MONITORING PROGRAM

STATION NO.	STATION LOCATION	LATITUDE	LONGITUDE	TYPE OF RECORD
	TRINITY-SAN JACINTO COASTAL BASIN			
0901.01	At SH 146, northeast of Baytown	294618	945500	CP
0902.01	At US 90 southwest of Dayton	295820	945910	C
	TRINITY-SAN JACINTO ESTUARY			
2421.01	At Houston Ship Channel marker 64	293300	945430	C
2421.02	At TSDH Sample Point GAL-00349 between Dollar Point and Houston Ship Channel	292640	945230	C
2421.03	At TSDH Sample Point WES-00A86 at Channel intersection near Teichman Point	291725	945325	C
2421.04	At TSDH Sample Point GAL-00226 in Trinity River Channel midway between Smith Point and Houston Ship Channel	293145	944900	CBPS
2421.05	At TWPD marker between Houston Ship Channel marker 71 and outer beacon of Seabrook Channel	293348	945812	CBS
2421.06	At FLR2 in Galveston Channel	291836	944954	CBS
2422.01	At TSDH Sample Point TRI-13-16B in Anahuac Channel at marker 1	294230	944345	CBS
2422.02	At Humble Oil Well 95 - flashing red light	293954	944712	C

TABLE I-E-01 (Contd.)
TEXAS WATER QUALITY BOARD
MONITORING PROGRAM

STATION NO.	STATION LOCATION	LATITUDE	LONGITUDE	TYPE OF RECORD
2422.03	At TSDH Sample Point TRI-10-11E just offshore at Point Barrow	294400	945000	C
2422.04	At pipe marker opposite Houston Lighting and Power Co. Cedar Bayou outfall	294500	944842	CBS
2423.01	At TSDH Sample Point EAS-00170, 3 nautical miles west of Marsh Point	293125	943730	CBSP
2423.02	At U. S. Corps of Engineers tide gage near Hanna Reef	292812	944236	C
2424.01	At Carancahua Reef	291245	950000	CBSP
2424.02	Midway between Alligator Point and San Luis Pass	290742	950724	C
2425.01	At SH 146 drawbridge	293255	950125	C
2425.02	At Channel marker 17	293330	950310	CBS
2426.01	Tabbs Bay, mid-bay at ruined bridge	294212	945906	CBS
2427.01	San Jacinto Bay at Buoy 15	294215	950054	C
2428.01	Black Duck Bay at mid-bay	294306	950036	C
2429.01	Scott Bay at mid-bay	294436	950224	C
2430.01	Burnett Bay at mid-bay	294054	950300	CBS
2431.01	Moses Lake at Channel marker 9	292620	945530	CBS
2432.01	At Chocolate Bayou Channel marker C-25	291205	951040	CBS

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TABLE I-E-01 (Contd.)
TEXAS WATER QUALITY BOARD
MONITORING PROGRAM

STATION NO.	STATION LOCATION	LATITUDE	LONGITUDE	TYPE OF RECORD
2437.01	At Texas City Ship Channel near Buoy 12	292224	955054	CBS
2437.02	At Texas City Ship Channel northwest of Snake Island at TSDH Station A-92	292345	945310	C
2438.01	Bayport Channel midway between mouth and terminus	293748	950010	CS
SAN JACINTO RIVER BASIN				
1001.01	At IH 10 east of Channelview	294730	950400	CBS
1001.02	At U.S. 90 east of Sheldon	295230	950536	CB
1002.01	Lake Houston at FM 1960 west of Huffman	300030	950830	C
1003.01	East fork of San Jacinto River at FM 2090 south of Cleveland	301254	950606	CBSP
1004.01	West fork of San Jacinto River at U.S. 75 south of Conroe	301436	952727	CBSP
1005.01	At Morgan's Point at TSDH Sample Point 00092	294040	945845	CBS
1005.02	Near front light of range T	294430	950336	C
1006.01	At San Jacinto Monument at TSDH Sample Point X-37	294515	950530	CBS
1006.02	At Green's Bayou confluence	294450	951004	C
1006.03	At Sim's Bayou confluence	294500	951430	C
1006.04	Near FL 165	294324	951312	C

TABLE I-E-01 (Contd.)

TEXAS WATER QUALITY BOARD

MONITORING PROGRAM

STATION NO.	STATION LOCATION	LATITUDE	LONGITUDE	TYPE OF RECORD
1006.05	Near FL 138	294424	950642	C
1007.01	At TSDH Sample Point X-10 in Turning Basin	294500	951720	CBS
1008.01	Spring Creek at IH 45, 20 miles north of Houston	300642	952615	C
1009.01	Cypress Creek at IH 45, 15 miles north of Houston	300209	952545	C
1010.01	Caney Creek at FM 2090, west of Splendora	301530	951815	C
1011.01	Peach Creek at FM 2090 at Splendora	301400	951010	C
1000.01	Green's Bayou at IH 10 east of Houston	294615	951154	C
SAN JACINTO-BRAZOS COASTAL BASIN				
1101.01	At SH 3 southeast of Webster	293115	950612	CP
1102.01	At FM 2351 west of Webster	293236	951151	C
1103.01	At SH 146 south of Kemah	292736	945827	C
1103.02	At SH 3 in Dickinson	292720	950255	CS
1104.01	At Arcadia - Cemetery Road north of Arcadia	292545	950654	C
1107.01	At FM 2004 south of Alvin	291218	951225	CSP
1108.01	At SH 35 southwest of Alvin	292006	951700	C

CURRENT USGS-TWDB MONITORING PROGRAM

The U. S. Geological Survey's stream monitoring program of Texas, conducted in cooperation with the Texas Water Development Board, is presented in Table I-E-02, which gives the USGS Station Number, description of location of current stations, exact location by latitude and longitude, and the type of data recorded from each station during water year October, 1972 to September, 1973.

USGS designations are used to express "type of record" and were derived from the "Index of Surface Water Stations in Texas", published by the U. S. Geological Survey. The USGS designations are:

C	Crest-Stage partial-record station
D	Streamflow discharge station
G	Gage heights only
L	Low-flow partial-record station
P	Periodic pesticide station
O_p	Periodic organic water-quality station
Q	Daily chemical-quality station
Q_c	Continuous-recording water-quality station
O_p	Periodic chemical-quality station
R	Reservoir-content station
S	Daily sediment station
B_p	Periodic biological station
S_p	Periodic sediment station

At each streamflow discharge station, a permanent gage is maintained from which a daily record of stage is obtained. Actual measurements of discharge are made to develop stage-discharge relation curves. Discharge records, showing the mean daily discharge in cubic feet per second, peak discharges for the major floods for each year, and total monthly and yearly runoff expressed in inches and/or acre-feet, are computed from basic hydrologic data on the basis of the water year ending September 30, 1973.

At partial-record stations, limited streamflow data are collected on a systematic basis over a period of years for use in hydrologic analysis. There are two kinds of partial-record stations:

A. Those operated for the purpose of defining annual maximum discharges, crest-stage partial-record stations; and

B. Those operated for the purpose of defining annual minimum discharges, low-flow partial-record stations.

At periodic organic-quality stations, biochemical oxygen demand (BOD), dissolved oxygen (DO), pH and nitrogen and phosphorus analysis are performed from 6 to 12 samples collected per year.

At each chemical-quality station, chemical constituents routinely measured include the principle inorganic ions, hardness, pH, SAR, specific conductance; and less frequently, the metals and several other selected ions such as bromide, boron, iodide and strontium. At most stations, samples are collected and temperature measurements are made on a daily basis. At daily stations where discharge records are available, discharge weighted averages of the chemical constituents are computed for each water year.

At the periodic chemical-quality stations, samples are collected for analysis at about one-month intervals. These stations are operated in conjunction with a streamflow station on a partial-record station, and attempts are made to collect samples over a wide range of discharges.

At pesticide stations, water samples are collected from 4 to 12 times a year. Bottom deposits from selected stations are analyzed four times per year. Pesticides analyzed are as follows:

A. In bottom deposits, insecticides analyzed are:

Aldrin
DDD
DDT
Dieldrin
Endrin
Heptachlor
Heptachlor epoxide
Chlordane
PCB

B. In water, all pesticides listed above are analyzed, plus:

Insecticides	Herbicides
Diazinon	2,4 - D
Malathion	2,4,5 - T
Methylparathion	
Parathion	Silvex

At each *reservoir-content station*, a daily record of stage is obtained.

At *periodic biological stations*, densities (colonies per 100 milliliters) of coliforms, fecal coliforms, and fecal streptococci are determined from 6 to 12 samples per year.

At *sediment stations*, quantity of sediment transported by streams is determined. Samples are collected on a daily, weekly, or periodic schedule for determinations of suspended load, partical-size distribution of suspend load and bed material, or unmeasured sediment discharge.

TABLE 1-E-02
U.S. GEOLOGICAL SURVEY
CURRENT INLAND MONITORING PROGRAM

STATION NO.	STATION LOCATION	LATITUDE	LONGITUDE	TYPE OF RECORD
CEDAR BAYOU BASIN				
08067500	Cedar Bayou near Crosby	295821	945908	$DQ_pO_pPB_p$
SAN JACINTO RIVER BASIN				
08067550	Welch Branch near Huntsville	303833	954047	C
08067580	Lake Conroe near Montgomery	302130	953330	R
08067610	Lake Conroe outflow near Conroe	302122	953337	D
08067650	West fork below Lake Conroe near Lake Conroe	302031	953234	DQ_pO_pP
08067750	Landrum Creek tributary near Montgomery	302103	954150	C
08067900	Lake Creek near Conroe	301512	953443	LQ_p
08068000	West Fork San Jacinto River near Conroe	301441	952726	DQO_pS_p
08068100	West Fork San Jacinto River near Porter	300336	951628	L

TABLE I-E-02 (Contd.)

U.S. GEOLOGICAL SURVEY

CURRENT INLAND MONITORING PROGRAM

STATION NO.	STATION LOCATION	LATITUDE	LONGITUDE	TYPE OF RECORD
SAN JACINTO RIVER BASIN				
08068300	Mill Creek tributary near Dobbin	301537	954614	C
08068400	Panther Branch near Conroe	301134	952909	$DQ_pO_pPB_p$
08068450	Spring Creek Panther Branch near Spring	300804	952838	$DQ_pO_pPB_pS$
08068500	Spring Creek near Spring	300637	952610	DS_p
08068600	Spring Creek near Humble	300204	951843	L
08068750	Cypress Creek near Cypress	295723	954041	LO_pP
08069000	Cypress Creek near Westfield	300208	952544	D
08069200	Cypress Creek near Humble	300149	951947	LO_pP
08069500	West Fork San Jacinto River near Humble	300137	951528	G
08069850	Bear Creek near Cleveland	302658	951311	C

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TABLE I-E-02 (Contd.)

U.S. GEOLOGICAL SURVEY

CURRENT INLAND MONITORING PROGRAM

STATION NO.	STATION LOCATION	LATITUDE	LONGITUDE	TYPE OF RECORD
SAN JACINTO RIVER BASIN				
08070000	East Fork San Jacinto River near Cleveland	302011	950614	DQP
08070200	East Fork San Jacinto River near New Caney	300843	950727	L
08070500	Caney Creek near Splendora	301534	951808	DS_P
08070600	Caney Creek near New Caney	300855	951131	L
08071000	Peach Creek at Splendora	301357	951005	D
08071100	Peach Creek near New Caney	300848	951016	L
08071200	Tarkington Bayou near Dayton '71	301123	950005	L
08071300	Luce Bayou near Huffman	300531	950503	L
08072000	Lake Houston near Sheldon	295458	950828	RO_PP
08072020	Lake Houston Municipal Water Purification Plant near Glena	294401	951258	P

TABLE I-E-02 (Contd.)

U.S. GEOLOGICAL SURVEY

CURRENT INLAND MONITORING PROGRAM

STATION NO.	STATION LOCATION	LATITUDE	LONGITUDE	TYPE OF RECORD
SAN JACINTO RIVER BASIN				
08072050	San Jacinto River near Sheldon	295234	950537	G
08072400	Buffalo Bayou near Clodine	294308	954353	C
08072500	Buffalo Bayou Barker Reservoir near Addicks	294611	953849	R
08072700	South Mayde Creek near Addicks	294728	954132	C
08072800	Langham Creek near Addicks	295008	953730	C
08073000	South Mayde Creek Addicks Reservoir near Addicks	294728	953724	R
08073500	Buffalo Bayou near Addicks	294542	953620	$DQ_pO_pPR_p$
08073600	Buffalo Bayou at West Belt Dr. at Houston	294543	953327	D
08073700	Buffalo Bayou at Piney Point	294448	953124	$DQ_pO_pPR_p$

TABLE I-E-02 (Contd.)

U.S. GEOLOGICAL SURVEY

CURRENT INLAND MONITORING PROGRAM

STATION NO.	STATION LOCATION	LATITUDE	LONGITUDE	TYPE OF RECORD
SAN JACINTO RIVER BASIN				
08073800	Bering Ditch at Woodway Drive at Houston	294522	952944	C
08074000	Buffalo Bayou at Houston	294536	952430	$DQ_pO_pPB_p$
08074150	Cole Creek at Deihl Road at Houston	295104	952916	D
08074200	Brickhouse Gully at Clarblak Street	294953	953142	C
08074250	Brickhouse Gully at Costa Rica Street at Houston	294940	952809	$DQ_pO_pPB_p$
08074500	Whiteoak Bayou at Houston	294630	952349	$DQ_pO_pPB_p$
08074550	Little Whiteoak Bayou at Houston	294705	952156	$LQ_pO_pPB_p$
08074600	Buffalo Bayou at Main St. at Houston	294554	952132	G
08074700	Buffalo Bayou at 69th St. at Houston	294515	951751	G

TABLE I-E-02 (Contd.)

U.S. GEOLOGICAL SURVEY

CURRENT INLAND MONITORING PROGRAM

STATION NO.	STATION LOCATION	LATITUDE	LONGITUDE	TYPE OF RECORD
SAN JACINTO RIVER BASIN				
08074800	Keegans Bayou at Roark Road near Houston	293923	953343	$DQ_pO_pPB_p$
08074850	Bintliff Ditch at Bissonnet St. in Houston	294116	953020	C
08075000	Brays Bayou at Houston	294149	952443	$DQ_pO_pPB_p$
08075100	Brays Bayou at Scott St at Houston	294235	952123	$LQ_pO_pPB_p$
08075300	Sims Bayou at Carlsbad Street at Houston	293733	952956	C
08075400	Sims Bayou at Hiram Clarke St. at Houston	293707	952645	$DQ_pO_pPB_p$
08075500	Sims Bayou at Houston	294027	951721	$DQ_pO_pPB_p$
08075550	Berry Bayou at Gilpin St.; Houston	293832	951322	C
08075650	Berry Bayou at Forest Oaks Street at Houston	294035	951437	$DQ_pO_pPB_p$

TABLE I-E-02 (Contd.)

U.S. GEOLOGICAL SURVEY

CURRENT INLAND MONITORING PROGRAM

STATION NO.	STATION LOCATION	LATITUDE	LONGITUDE	TYPE OF RECORD
	SAN JACINTO RIVER BASIN			
08075730	Vince Bayou at Pasadena	294140	951258	D
08075760	Hunting Bayou at Falls Street at Houston	294822	951950	$CQ_pO_pPB_p$
08075770	Hunting Bayou at U.S. Hwy 90-A at Houston	294735	951604	$DQ_pO_pPB_p$
08075780	Greens Bayou at Cutten Road near Houston	295656	953110	C
08075900	Greens Bayou at U.S. Hwy 75 near Houston	295724	952504	D
08076000	Greens Bayou near Houston	295505	951824	$DQ_pO_pPB_p$
08076200	Halls Bayou at Deertrail Street near Houston	295407	952521	C
08076500	Halls Bayou at Houston	295142	952005	$DQ_pO_pPB_p$
08076700	Greens Bayou at Ley Road at Houston	295013	951359	$DQ_pO_pPB_p$
08076900	Carpenters Bayou at Cloverleaf	294621	950921	$LQ_pO_pPB_p$

TABLE I-E-02 (Contd.)

U.S. GEOLOGICAL SURVEY

CURRENT INLAND MONTIORING PROGRAM

STATION NO.	STATION LOCATION	LATITUDE	LONGITUDE	TYPE OF RECORD
CLEAR CREEK BASIN				
08077000	Clear Creek near Pearland	293550	951711	D
08077100	Clear Creek Tributary at Hall Road	293609	951641	C
08077510	Clear Creek above Turkey Creek near Friendswood	293336	951157	L
08077550	Cowart Creek near Friendswood	293046	951321	C
08077600	Clear Creek near Friendswood	293102	951042	C
08077620	Armand Bayou near Genoa	293802	950651	L
COASTAL BASIN				
08077650	Moses Lake-Galveston Bay near Texas City	292650	945512	G
HIGHLAND BAYOU BASIN				
08077700	Highland Bayou at Hitchcock	292112	950149	G

TABLE I-E-02 (Contd.)

U.S. GEOLOGICAL SURVEY

CURRENT INLAND MONTIORING PROGRAM

STATION NO.	STATION LOCATION	LATITUDE	LONGITUDE	TYPE OF RECORD
HIGHLAND BAYOU BASIN				
08077750	Highland Bayou Tributary near Texas City	292031	945703	C
CHOCOLATE BAYOU BASIN				
08078000	Chocolate Bayou near Alvin	292209	951914	D
OYSTER CREEK BASIN				
08079000	Oyster Creek near Angleton	290930	952832	D
COASTAL BASIN				
08079100	East Levee Ditch- Gulf of Mexico near Freeport	285738	951834	G
08079150	South Levee Ditch-Gulf of Mexico near Freeport	285528	952123	G

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WATER QUALITY MONITORING PROGRAM SUMMARY

Prepared by the
City of Houston Health Dept. *
Water Pollution Control

INTRODUCTION

The following is an edited summary of the report on existing water quality monitoring programs within the Greater Houston 208 Planning Area as prepared by the City of Houston Department of Health. Tabulations of water quality monitoring points and their locations which are summarized elsewhere in this report are not repeated in this summary to avoid repetition. Otherwise, the document is as submitted to H-GAC by the Health Department.

Rice University

The Environmental Engineering Department of Rice University in September, 1973 began a monitoring program of the Woodlands Watershed in an effort to determine the effects of a unique water management plan designed to utilize the benefits of the existing natural drainage, while attempting to avoid the adverse water quality conditions and hydrological effects of urbanization. Using three U.S.G.S. monitoring stations, the university team collected and analysed grab and composite samples during dry weather conditions as well as during storm events. Routine sampling was conducted on a bi-monthly schedule.

The team was composed of four full-time and two part-time faculty members with a member of the University of Texas School of Public Health Dr. Ernest Davis, conducting the laboratory work. The fully-equipped Rice laboratory includes a technician auto-analysis (sic). The composite sampling was accomplished with an Isco Wastewater Sampler. The samples were analysed for: pH, temperature, COD, TOC, NO_3, NH_4, NO_2, ortho-PO_4, PO_4, TSS, Conductivity, and turbidity.

Future plans for Rice's Environmental Engineering Department include development of a dynamic mathematical model for water resource management which will be based on water data collected by the Houston Health Department, Water Pollution Control. The samples will be collected during storm events on Buffalo Bayou from Shepherd Drive to Dairy-Ashford Road and analyzed by the Health Department Laboratory.

These projects are funded by federal grants from the Environmental Protection Agency.

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* Barbara Keeton, Principal Author

Texas Water Quality Board

Under authority granted by the Texas Water Quality Act, 1967, the Texas Water Quality Board indicated its stream monitoring program in October, 1968, and is funded by federal and state appropriations. The State of Texas is divided into twelve Districts. Harris County is one of nine counties within District Seven.

The average operation and maintenance cost per water quality monitoring station per year is approximately $1,000.00. The average time requirement is two man hours per sample for stream samples and four man hours per sample for estuarine samples. Travel, collection of samples, laboratory expenses, and equipment use are included in the above estimates sample costs. There are 46 stream quality monitoring stations and 44 estuarine quality monitoring stations in District 7. Included in the stream stations are two stations on Lake Conroe and one on Lake Houston. All stations are sampled quarterly, except for the stations on the Houston Ship Channel that are sampled monthly. All samples are analyzed at the Environmental Protection Agency lab located in Houston. The samples are jointly analyzed by both Texas Water Quality Board and Environmental Protection Agency Personnel. Quality control is as prescribed by the Environmental Protection Agency.

As always, future plans depend largely on funding. As long as adequate funds are available, every attempt is made to do what is necessary to insure that all major water areas are adequately monitored to protect the waters of the State. As the state of the art progresses for Water Quality monitoring, every attempt will be made to upgrade all aspects of the Statewide Monitoring Network Program.

United States Geological Survey

USGS began its stream monitoring program on the San Jacinto River Basin in 1929. Members of USGS work in teams sampling the network of stations on approximately a once a month basis. Each team is out one week at a time, gathering grab samples. Flow and rain measurements from permanently-installed gages are recorded continuously. Field teams test for DO, temperature, and conductivity in the field and send samples to laboratory substations in Houston or Austin for BOD and bacterial coliforms tests. Other samples are frozen and shipped to the central laboratory in Denver or Atlanta to test for inorganics. All analyses are made with Strict adherance to the USGS Standarized Methods Manual. The parameter values are then fed into a computer which will immediately flag any value which falls outside a determined average. In such an event, the sample which has been flagged is retested. After all tests have been made and evaluated by the computer, the values are then sent back to each substation to be manually checked for standard deviation, precision, and accuracy. If a discrepancy is found at this point, retesting is ordered. After all values and calculations have been double-checked, the data is then stored in the computer banks in Washington, D.C.

Field tests and laboratory analyses include instantaneous discharge; dissolved silica, calcium, magnesium, sodium, sodium plus potassium, potassium, bicarbonate, carbonate, dissolved sulfate, chloride, fluoride, total nitrate, nitrite, ammonia nitrogen, organic nitrogen, total kjeldahl-nitrogen, total phosphorus, dissolved solids (sum of constituents), total non-filtrable, volatile non-filtrable, hardness, non-carbonate hardness, sodium adsorption ratio, specific conductance, pH, temperature, turbidity, DO, BOD, various coliforms, TOC, phenols, Al, As, B, Cd, Cr, Co, Cu, Fe, Pb, Li, Mn, Hg, Ni, Sr, Zn, Aldrin, DDD, DDE, DDT, Chlordane, PCB, Diazenon, Malathion, Methylparathion, parathion, 2, 4-D, Silvex, 2, 4, 5-T.

Funding for USGS is appropriated by Congress on a project co-op basis. That is, one half of the budget for a project is supplied by federal funds and the other half is supplied by the city or county requesting the job. In 1976, the stream monitoring for the City of Houston area had a budget of about $52,000.

Early in 1976, USGS had no plans for expanding any of its current programs nor of creating any new programs. However, eventually USGS hopes to implement a remote, telemetric stream monitoring system.

City of Houston Health Department, Water Pollution Control

Created in 1971 by City Council in compliance to Senate Bill 835, the Water Pollution Control Division began functioning with a budget of $100,000, a seven man team, and seven vehicles. The original program called for vehicle reconnaissance of the two thousand square miles which comprises the City of Houston and its extraterritorial jurisdiction. Besides checking for visible evidence of oil emmission, the team collected monthly grab samples from ten stations along each of the six major bayous and Galveston Bay. Samples were analyzed for pH, DO, BOD, conductivity, Total Coliform, Fecal Coliform, PO_4-P, COD, NH_3N, NO_2-H, NO_3-N, and Oil and Grease. The standardized Methods Manual for Laboratory Analysis was used then, as it is now, with strict adherance to precision and accuracy.

By the end of 1971, 3748 inspections had been made, 3369 advisory visits, 469 field tests, and 4500 samples analyzed. Out of the 483 violations found that year, 376 had been corrected by the close of 1971.

The Division has now expanded to approximately fifty members and a budget of nearly one million dollars. A one-half million dollar equipment inventory includes sixteen vehicles, two boats, car radios, a pageboy communication system, two atomic absorption analysers, cameras, and various water analyzer meters for field use.

Routine monitoring programs now include the City of Houston wastewater treatment plants, industrial outfalls, permitted by the Texas Water Quality Board, and the six major bayous. In addition to the original parameters analyzed, tests for heavy metals and total suspended solids are conducted. The EPA Standard Methods Manual and TWQB quality control methods are used in the laboratory for precision and accuracy control.

Future plans for the Water Pollution Control Division include flow measurement, in-stream monitoring, and a monitoring program for Lake Houston.

Earth Awareness Foundation

Earth Awareness Foundation was created in May, 1970, as a non-profit educational advisory organization by the United States Astronauts and key members of the nation's aerospace management team. The Foundation's prime objective is to aid in creating a healthy environment for future generations. Funded by private individuals, interested citizen donation, and business interests along the Texas Gulf Coast, the Clear Creek Basin Project study, included in the Water Data Base of Section "208", has a present budget of $50,000 for the next five (5) years.

The function of the Foundation is to assist and work with various public service and volunteer programs in promoting public awareness of environmental issues. In this effort, the Foundation selects top academic students to work twelve (12) weeks each summer in an environmental survey and research program to study and record existing water conditions.

In 1971, twelve (12) high school students were selected. The students work from 8:00 A.M. to 5:00 P.M. four days a week and until midnight one day each week to assure completion of certain long and involved analytical labortary tests which cannot be interrupted. During the course of study and data gathering, the students visit chemical and municipal plants observing antipollution and laboratory, analytical systems and programs Via boats and canoes the students collect their water samples to process in their laboratory.

In 1974, the program included thirty high school participants, each receiving up to $250 in scholarship grants. These students collected over 500 samples from 40 different stations in the Clear Creek Basin, all of which were biologically and chemically analyzed in local high school laboratory facilities with technical help provided by Gulf Waste Disposal Authority. Quality Control followed EPA Standard Method Guidelines.

Parameters tested included temperature, DO, BOD, pH, Alkalinity, NO_3, PO_4, SO_4, Conductivity, and suspended solids.

The project findings are published in an annual report and sent to various federal and state water pollution control agencies and interested individuals.

Environmental Protection Agency

In November, 1973 the Environmental Protection Agency was created in an attempt by President Nixon to place all previously created pollution control agencies under a single organization. The new agency was to use a five-fold method approach to bring the nation's environment back to a safe and desirable equilibrium:

1. Identification of pollutants
2. Tracing the path of pollutants through the environmental chain while observing and recording any changes in form
3. Assessing the effects on human health and welfare of exposure to pollution
4. Keeping a watchful eye for synergistic effects among pollutants
5. Locating an optimum point in the ecological chain for interdiction.

In brief, the EPA focus is on setting and enforcing pollution control standards whose authority supercedes state and local governments. The EPA stream monitoring data included in the EPA study of the Houston area was collected during the months of May, June, and July, 1974 and January, 1975 was done on a voluntary basis. Tests were conducted for pH, D.O., temperature, salinity, conductivity, nitrates, nitrites, ortho-phosphates, phosphates,, TOC, and many types of nektons. Laboratory testing was conducted under the direction of Dr. William Langley who adheres to EPA Standard Methods and exercises strict quality control. The EPA Standard Methods is a laboratory analysis guide available to the public.

The EPA stream monitoring effort was a temporary, nonfunded effort with no plans for future monitoring programs.

Galveston County Health District

The Galveston County Health District Water Pollution Control and Abatement Program was initiated in January, 1972. The boundaries of authority include all of Galveston County, both incorporated and unincorporated areas. Acting in compliance of Senate Bill 835, the District is funded primarily by the six cities within Galveston County with populations greater than 5,000 and some support from the remaining Health District members (Kemah and Clear Lake Shores, W. C. & I. D. No. 1 (Dickinson).

The Health District is directed by Dr. W. W. Kemmerer, Jr. and a three-man team who spends approximately 65% of their time in water pollution control activities. The laboratory work is performed by three people in the district's Environmental Chemistry Laboratory and by six people in the Bacteriology and Serology Laboratory. The 14th edition of Standard Methods for Examination of Water and Wastewater is followed precisely by both labs for all analyses.

Galveston County Health District routinely monitors 118 sampling points. Monthly samples are collected at 33 stations, 82 stations are sampled bi-monthly, and 3 stations are samples bi-monthly, and 3 stations are monitored quarterly. Field personnel collect all samples. A 100-ml. sample for fecal coliform analysis is collected on each sample station visit, additionally the following information is recorded: Date, time, wind direction and estimated speed, cloud cover, recent or current rainfall, tidal activity or flow, air temperature, water temperature, dissolved oxygen, salinity, conductivity, observed color and turbidity (relative to normal conditions) and any unusual of abnormal observations. A one litre grab sample is collected a minimum of three or four times annually from all stations, except those located on the Galveston Island beach, for additional analysis. This program normally includes BOD, COD, total suspended solids, pH and nutrient analysis.

All permitted wastewater discharges located in Galveston County are monitored regularly, normally quarterly, to insure compliance with their state and federal discharge permits.

The Bacteriology Lab normally runs only total and fecal coliform analyses for this program utilizing both the multiple tube and Milipore filter techniques. Quality control is carried out in cooperation with the Texas Department of Health Resources.

The Environmental Chemistry Laboratory is limited on the types of analysis it can perform due to the absence of such equipment as an atomic absorption unit (heavy metals) and a Total Organic Carbon analyzer. This lab is currently participating in a cooperative quality control program with the Gulf Coast Waste Disposal Authority and its various wastewater laboratories. Future plans include possibly a TOC Analyzer.

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